UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

THE EVAPORATION OF GRAPES

BY

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BULLETIN No. 322

JUNE, 1920

UNIVERSITY OF CALIFORNIA PRESS
BERKELEY
1920

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I. PURPOSE OF THE INVESTIGATION

Drying has proved to be one of the most feasible methods of converting the wine grapes of California into a non-perishable salable product. In the hot interior valleys, where the grapes ripen early, the fruit may be dried successfully on field trays in the vineyard.

However, at least 50 per cent of the wine grapes are grown in regions where the grapes ripen so late that sun-drying can not be safely undertaken, because of the danger of loss through early fall rains.

In the raisin-growing districts, serious loss from early rains to Sultanina and Muscat grapes on drying trays has occurred several times during the past ten years. Some provision should also be made for utilizing the second-crop Muscat grapes which in former years have been sold to wineries and distilleries. These grapes ripen too late in the fall to permit of drying them in the sun. In the aggregate, they amount to many thousand tons, and formerly were a source of considerable revenue to the raisin growers.

The cull Tokay and other cull table grapes from the packing houses and the inferior bunches left on the vines have been used principally for wine making in past years. Much of the brandy used in the manufacture of sweet wine was made from this cull fruit and resulted in a small return to the grower.

It is contended by many that a greater yield and a better quality of raisins are obtained by artificial drying in an evaporator than in the sun.

Because of these important reasons it is imperative that there be available for producers of all varieties of grapes reliable information on the construction and operation of evaporators for the drying of raisin grapes, wine grapes, cull table grapes, and second-crop Muscats. The investigations recorded in this publication were carried out for the purpose of obtaining such information. While the magnitude of the problem has made its completion in the one season's time devoted to it impossible, we believe the results obtained to date are sufficiently important and conclusive to warrant their publication.

Most of the data reported were obtained in the commercial evaporator at the University Farm, Davis, although a great many small-scale experiments were made in our experimental evaporators at Berkeley.

II. ACKNOWLEDGMENTS

The erection of an evaporator of commercial size was made possible by a grant of $2500 from the State Board of Viticultural Commissioners with which the equipment and most of the building materials for the evaporator were purchased.

Through the courtesy of Dr. J. C. Whitten of the Division of Pomology, a portion of the Deciduous Fruits Appropriation passed by the last State Legislature was applied in the employment of a

chemist who coöperated in carrying out the investigations. Without these two special funds very little investigational work could have been performed.

The writers wish to thank Professor F. T. Bioletti for the valuable suggestions given during the planning and construction of the evaporator and during the investigations.

III. PRINCIPLES OF EVAPORATION

The construction of evaporators and the discussion of the experimental results will be better understood if the more important principles and previously existing data on fruit evaporation. Evaporators of many types have been used with varying degrees of success for many years. From the experience gained in the use of these evaporators and from observations and measurements taken by scientific investigators certain principles have become recognized. To this existing knowledge new information is being constantly added and some of the older theories are being discarded or seriously modified.

(*a*) NECESSITY OF HEAT

Evaporation of fruits involves the change of water from the liquid to the vapor state. This change requires the expenditure of a very definite amount of heat regardless of the system of evaporation and the temperature used. This quanitity of heat is known as the "latent heat of vaporization" and is equal to the amount of heat given off when steam condenses to water.

Expressed in the usual heat-unit terms, approximately 965 British Thermal Units of heat are required to evaporate one pound of water. A British Thermal Unit (B. T. U.) is the amount of heat used in raising one pound of water one degree Fahrenheit. To the heat actually used in evaporation must be added that needed to raise the fruit from its original temperature to that of the evaporator. This ordinarily amounts to 50 to 75 B. T. U. per pound of fruit; thus making the total minimum quantity of heat necessary slightly above 1000 B. T. U. per pound of water evaporated.

The fuel efficiency of an evaporator may be judged by its approach to this minimum in its heat requirements. If the drying ratio of the fruit, the weight of fruit evaporated, the quantity of fuel consumed, and the heat value of the fuel are known, the heat efficiency of the evaporator may be calculated. In most evaporators it will be found that not over 50 per cent of the heat generated in the furnace is utilized in drying the fruit because of the heat lost by radiation and leaks in the evaporator and the heat lost in the exhaust air. This last loss is the greatest. A typical case will show its magnitude. If the outside air at 80° F. is heated to 160° F., as it enters the evaporator, and if it leaves the evaporator at 120° F., it is readily seen that only 40° F. of the 80° F. rise in temperature is utilized, or less than 50 per cent of the heat is utilized in drying, if we include radiation and other minor losses of heat.

Many evaporators have failed because they have not been supplied with sufficient heat. The air heating system must have adequate capacity and should supply an abundance of heat without the need of forcing the furnace. The attempt to force the furnace beyond its capacity has been a very common cause of loss of evaporators by fire.

(*b*) MODES OF CONVEYING HEAT

Heat may be applied or conveyed to the fruit in several ways. It may be conducted by direct contact of the fruit with the heating system. This method of conveying the heat has not been used in practice to any appreciable extent because the high temperatures of the heating element would scorch the fruit. In European countries community bake ovens are often used for drying fruits after the bread has been removed, the fruit in many cases resting in contact with the hot bricks of the oven.

Heat may to a limited degree reach the fruit by radiation, just as heat is radiated into a room from a fire place or stove. In the stack and tunnel types of evaporators it is probable that this mode of heat transfer is of appreciable importance but in the average air-blast type of evaporator it is negligible.

By far the most important method of heat transfer is by air currents, which may, if we use the term rather loosely, be termed "transfer of heat by convection." The air is heated by contact with a furnace, radiating pipes, or other heating system, and the heated air rises through the drying compartment because it is lighter than the outside air or it is transferred over the fruit to be dried by means of a fan.

(*c*) NECESSITY OF AIR CIRCULATION

Since a large amount of heat is essential for successful drying and since air is the usual vehicle for transfer of this heat from the furnace to the fruit the necessity of air circulation in the evaporator can be seen. Just how important this factor is, may be seen from the following consideration. It will require approximately 63,000 cubic feet of air dropping one degree Fahrenheit to furnish 965 B. T. U., the heat necessary to evaporate one pound of water; or it will require approximately 1575 cubic feet of air dropping 40° F. to furnish this amount of heat. A 40° F. drop in temperature is probably greater than that taking place in the average evaporator; consequently, 1575 cubic feet of air per pound of water evaporated may be considered in the nature of the minimum air requirement. An evaporator holding 5 tons of grapes which dry in 24 hours and which have a drying ratio of 3:1 must evaporate 6666 pounds of water per 24 hours, or 4.6 pounds per minute. This will require a minimum of $4.6 \times 1574 = 7245$ cubic feet of air per minute. If the drying period is 12 hours, approximately 14,500 cubic feet of air per minute will be needed. A few evaporators have during the past season dried wine grapes in twelve hours but twenty-four hours time or longer was required in most cases. In our small evaporator at Berkeley which was supplied with an excess of air, grapes were dried in from six to twelve hours, indicating the possibilities of reducing the drying period of grapes by increasing the air supply, which means also increased heat supply.

(*d*) HUMIDITY CONTROL

Air circulation is also important as a means of carrying away the moisture evaporated from the fruit by the heat. In a "dead air" space, heated fruit for a short time rapidly gives up its moisture to the surrounding air which soon becomes saturated and further evaporation ceases unless the saturated air is replaced by fresh dry air. The moisture-carrying capacity of air is relatively limited; hence, a large volume of air must pass over the fruit to carry away the moisture if drying is to be continuous and rapid. A rough conception of the amount of air needed for this purpose under average conditions may be had from the following consideration.

At 101° F., approximately 350 cubic feet of air at the saturation point is required to carry one pound of water. At 128° F., this same volume of air will hold at saturation two pounds of water vapor, and at 155° F., four pounds of water vapor; that is to say, each 27° F. rise in temperature will double the moisture-absorbing power of the air. At 120° F., 350 cubic feet of air will absorb about 1¾ pounds of water vapor.

These figures refer to air saturated with moisture vapor; that is, air of 100 per cent relative humidity. Relative humidity may be defined as the percentage of saturation of air with water vapor, although the condition applies also to a space which may be free from air. In most commercial evaporators, however, we are dealing with air.

Few evaporators raise the relative humidity of the air above 50 per cent. If the air leaves the evaporator at 50 per cent relative humidity and at 120° F., it will carry approximately 1¾ pounds of water vapor per 350 cubic feet or each 1000 cubic feet will carry approximately five pounds of moisture. For an evaporator drying 5 tons of grapes per 24 hours, approximately 5 pounds of water must be removed from the grapes per minute, or at least 1000 cubic feet of fresh air must be drawn through the evaporator per minute to carry away the moisture.

In the above calculations to determine the amount of air necessary to carry the required amount of heat to the fruit it was found that approximately 7245 cubic feet of air per minute was required. Comparing this result with the amount of air needed to carry away the moisture we find that about seven times as much air is needed to furnish heat for evaporation as is necessary to carry away the water evaporated by this heat. If this extra six-sevenths of the air is allowed to escape, much fuel value and much of the moisture-carrying capacity is wasted. If six-sevenths of the air under the above assumed conditions be returned to the furnace room and mixed with one-seventh of fresh air and if one-seventh of this mixture after reheating and passage through the evaporator be allowed to escape at 50 per cent or greater relative humidity it is readily seen that the efficiency of the evaporator is greatly increased.

This recirculation of the air is not only theoretically more efficient but is of great value in practice for other reasons. If the air is too dry and of high temperature, moisture may be taken from the surface of the fruit more rapidly than it can effuse from the interior, resulting in the formation of a hard shell on the surface, or "case hardening," which retards subsequent evaporation. If the humidity of the air is relatively high, diffusion keeps pace with evaporation and case hardening is prevented. A second advantage of the higher humidity of the air is in preventing the over-drying of fruit; because drying will cease when the fruit and air arrive at the same relative moisture content. Grapes tend to dry unevenly and many to over-dry in an atmosphere of very low humidity; that is, in very dry hot air. A third advantage of the higher humidity is its tendency to reduce the injurious effects of high temperatures on the fruit flavors. It is therefore possible to use higher temperatures of drying with humid air than with dry air.

Because of the vital importance of controlling the humidity of the air used in drying, prospective purchasers and manufacturers of evaporators are advised to install in their plants some means of effectively regulating the moisture content of the air. One of the most effective methods of increasing the humidity of the air to the desired degree, is that of returning a part of the exhaust air from the evaporator to the furnace room where it is mixed with fresh air, reheated and passed over the fruit again. By varying the proportion of the recirculated air any desired degree of humidity may be maintained. As already pointed out, recirculation of a part of the air results in a great saying of fuel.

By way of summary it may be stated that (1) evaporation of water from a free surface varies inversely as the relative humidity, (2) directly as the time, (3) directly as the temperature, and (4) as the square root of the air velocity. Dipped grapes more nearly approach a free surface of water than do most fruits, because of their small size and, therefore, the above relations will probably be more nearly true for grapes than for other fruits.

(*e*) MISCELLANEOUS REQUIREMENTS

In addition to providing for the fundamental requirements of adequate heat supply, air circulation and control of humidity, the evaporator to be thoroughly satisfactory should include the following features:

It should utilize its fuel efficiently. This means that the transfer of heat from the furnace to the air should be as complete as possible, with very little of the heat escaping through the smoke stack. It also means that radiation losses and losses through leaks should be minimized.

The evaporator should be as conveniently arranged as possible in order to reduce labor costs to a minimum. This is a very important point that some manufacturers have overlooked. Frequent shifting of the trays in some evaporators greatly increases the labor cost: a practice made necessary by uneven air distribution in the evaporator and uneven drying of the fruit on the trays.

The evaporator should be so arranged in relation to the dipper, spreading tables, sulfur house, stemmer, storage bins, etc., that the fruit can be handled efficiently at all points. This will require careful arrangement of the plant.

It is the opinion of the writers that all evaporators representing any considerable investment should be of fireproof construction. The slight extra cost is an excellent investment.

The cost of an evaporator for grape drying must not be excessive if the investment is to prove profitable. On the other hand, the evaporator should not be of such cheap construction that its period of usefulness will be excessively short. At 1919 prices for materials, it is believed that a substantially constructed evaporator similar in design to the University Farm Evaporator described below can be erected and equipped for about $500 per fresh ton capacity per 24 hours.

IV. THE UNIVERSITY FARM EVAPORATOR

This evaporator was constructed primarily for the purposes of conducting investigations in the drying of grapes and other fruits upon a commercial scale and to convert the grape crop of the University Farm into a marketable product. It was also hoped that the evaporator would serve as a model for growers who might wish to build evaporators.

The discussion of the evaporator has been taken up under the following topics: List of Materials and Cost of Construction, Description of the Evaporator as Used in 1919, Course Followed by Grapes at Evaporator, and Suggested Revisions in Plan of University Farm Evaporator.

(*a*) LIST OF MATERIALS AND COST OF CONSTRUCTION

The materials, labor, and equipment entering into the construction of the Davis evaporator are given in the following list:

1. Lumber:

6″ × 6″ rough redwood	152 linear feet	
2″ × 6″ S-2E Oregon pine	950 " "	
1″ × 6″ pine sheathing	3500 " "	
2″ × 4″ S-4-S Oregon pine	400 " "	
2″ × 4″ rough pine for yard track	360 " "	
1″ × 4″ T & G flooring	4100 " "	
2″ × 8″ rough pine	82 " "	
4″ × 6″ rough pine	88 " "	
4″ × 4″ rough pine	64 " "	
4″ × 4″ S-4-S Oregon pine for dipper	8 " "	
3″ × 4″ S-4-S Oregon pine for dipper	20 " "	
2″ × 3″ S-4-S Oregon pine for dipper	8 " "	
2″ × 12″ rough pine	300 " "	
19,000 redwood shingles		
		$679.99

2. Labor: 137½ days at $5.00 per day		687.84
3. Plumbing materials for water and fuel supply		28.33
4. Electrical equipment and supplies:		
(*a*) 1 7½ h.p. 3-phase, 110-volt motor for fan	$188.80	
(*b*) 2 transformers, complete	97.50	
(*c*) Wire	117.72	
(*d*) 2 poles	18.80	
(*e*) Switches, light sockets, insulators, cross arms, fuse plugs, etc.	25.95	
		448.77
5. Hardware:		
(*a*) Heating pipe, 12″ riveted: 6 pieces 8′ long, 2 pieces 1′ long, 2 pieces 20′ long, 6 return bends, and 2 elbows	$135.00	
(*b*) 2 old boiler shells, 6′ × 3′	100.00	
(*c*) 1 California-Fresno large size gravity burner	22.50	
(d) 1 Johnson whirlwind distillate burner, medium size	85.00	
(*e*) 1 54″ disc fan (American blower)	182.00	
(*f*) 1 60″ disc fan (American blower)	239.70	
(*g*) 1 50-gallon cauldron	25.00	
(*h*) 2 22″ prune dipping baskets	17.00	
(*i*) 1 set roller bearings for dipper	17.50	
(*j*) 250′ iron T-rail, 8 pounds per yard	39.57	
(*k*) 3 all steel lower dry-yard transfer trucks	56.25	
(*l*) 13 wooden frame dry-yard trucks	73.13	
(*m*) Hinges, nails, wire washers, furnace doors, etc.	35.71	
		1028.36
6. Materials for 500 trays:		
(*a*) Shook: 1000 pieces, 1½″ × 1½″ × 36″; 1000 pieces, ⅞″ × 1½″ × 33″; 1000 pieces, ⅞″ × 1½″ × 36″; 1000 pieces, ⅜″ × ⅞″ × 33″; 500 pieces, ⅞″ × 1″ × 33″; 500 pieces, ⅜″ × ⅞″ × 34″; 1000 pieces, 1″ × 1½″ × 36″ for side cleats to raise height of trays	$90.00	
(*b*) Wire: 1200 linear feet, ½″ mesh; 300 linear feet, ¼″ mesh; 300 linear feet, ⅓″ mesh	253.45	
		343.45
7. Cement, bricks, etc.:		
(*a*) 128 sacks of cement	$147.34	
(*b*) 1000 second-hand brick (no charge)		
(*c*) 400 fire brick	32.00	
(*d*) 160 pounds of fire clay	4.80	
(*e*) 3 loads of crushed rock	6.00	
(*f*) 4 loads of sand	8.00	
(*g*) 17 loads of creek gravel (no charge)		
(*h*) 1½ barrels of lime	4.50	
		202.64
8. Paint for roof and stacks		41.75

9. Thermometers:		
(*a*) 1 recording thermometer	$52.50	
(*b*) 2 angle-stem Fahrenheit thermometers	39.60	
		92.10
10. Belting:		
(*a*) 25′ of 4″ rubber belting (estimated)	13.25	
(*b*) 10′ of 4″ leather belting, second hand (estimated)	10.00	
(*c*) Belt lacing	.25	
		23.50
11. Miscellaneous		5.91
Total		$3582.64

The cost of an evaporator of this capacity (6 tons of fresh fruit per charge) to the average builder at 1919 prices for materials would be considerably less than the total given above for the following reasons. The furnace room is twice as large as necessary and the outside walls were given a special finish. One furnace and one burner were found to be sufficient, although for experimental purposes two of each were installed. The shed above the evaporator was built very substantially of such design and finish as to compare favorably in appearance with other buildings on the University Farm. A shed less attractive in appearance but equally serviceable would probably be built by the average grower. One fan was sufficient, although for experimental purposes two were installed. However, these fans were of an inexpensive type and one multivane fan to replace them would cost as much as the two disc fans actually installed. The sulfur house was built of cement; a wood sulfur house will answer. Taking all such possible savings in cost into account it is believed that an evaporator of the same design and capacity as our plant could be built and equipped for about $3000, or at a cost of about $500 per fresh ton capacity per charge.

(*b*) DESCRIPTION OF THE UNIVERSITY FARM EVAPORATOR USED IN 1919

The evaporator consists of a tunnel through which the cars loaded with fruit are moved during drying and a fire-proof furnace room for heating the air which is drawn or blown through the tunnel by a fan. The remaining equipment is used for preparing the fruit for drying or for packing the dried product.

The drying tunnel and dipping outfit are housed beneath a shed approximately 60 feet long and 20 feet wide. The general appearance of the complete plant may be seen from the accompanying photograph.

The tunnel is 33 feet long by 7 feet high by 6½ feet wide, inside dimensions. The walls and ceiling are constructed of 1″ × 4″ tongue and groove pine on an outside framework of 2″ × 4″ pine. The floor is of cement and slopes toward the furnace room to aid in moving the cars forward. The slope is ¼ inch per foot; for the type of cars used, this slope could be considerably increased to advantage.

The location of the two doors may be seen from the accompanying sketch. The door openings are 7 feet high by 64 inches wide and each is closed by two tight-fitting folding doors. Transfer tracks enter each door and connect with the tunnel track. The transfer track rails are 42 inches apart and are ordinary dry-yard T rails of 8 pounds

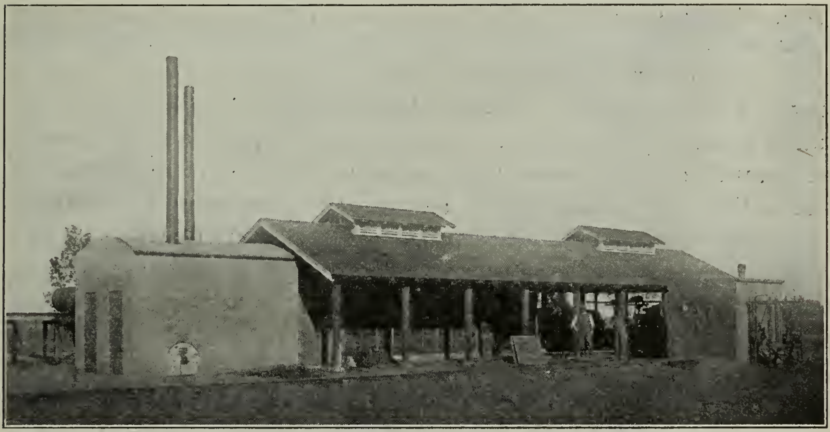

Fig. 1.—View of the University Farm Evaporator.

per yard weight. The tunnel track rails are set 24 inches apart and connect with the transfer tracks at each end of the tunnel.

An air return flue 1 foot high by 6½ feet wide and 33 feet long rests above the drying tunnel. This connects with the tunnel outlet by a door 1 foot by 6½ feet which folds upward and by a door of the same size in the furnace room. The return flue is constructed of 1″ × 4″ tongue and groove over 2″ × 4″ pine. It is used for the return of a part of the exhaust air to the furnace room where it may be mixed with fresh air, reheated, and recirculated.

The tunnel connects with the furnace room through a 60-inch disc fan. A 54-inch disc fan is located at the other end of the tunnel. A 7½ h.p. electric motor is used to operate either fan. The fans and motor have pulleys of such size that the 60″ fan is operated at 300 r.p.m. and the 54-inch fan at about 350 r.p.m. When operated at the above speeds either fan should deliver 25,000 cubic feet of air per minute (catalog rating). The two fans were installed merely for the purpose of comparing a blast fan with a suction fan.

The furnace room is 16 feet long by 12 feet wide by 12 feet high, outside dimensions. The walls and roof are of 6-inch reinforced concrete. Two old boiler shells, each 6 feet long by 3 feet in diameter, open at one end for installation of burner, and connected at the other end to a 12-inch pipe, have been placed on opposite sides of the furnace room, as shown in figure 2. Each furnace is connected to three lengths of 12-inch heavy gauge sheet iron pipe which is led back and forth above each furnace before connecting to the smoke stack extending 20 feet above the furnace room. The hot gases from the furnace must travel a distance of 40 feet through the radiating pipes in the furnace room before reaching the stack. One furnace is fitted with a gravity burner and the second with an air-blast burner. Fuel is supplied to the burners through ¼-inch pipes connected to a 110-gallon distillate drum placed on a platform 5 feet above the ground. In the wall of the furnace room opposite the tunnel are located two sets of three doors each for the admission of fresh air to the furnace room and tunnel. One set of doors is opposite each furnace. Each door is about 28 inches by 20 inches in size. (See figs. 1 and 2.) The amount of air admitted to the evaporator is regulated by adjusting these doors.

The dipping equipment is located under the east end of the evaporator shed. It consists first of a 50-gallon prune-dipping cauldron mounted over a brick furnace in which is burned coal or wood to keep the lye solution in the kettle at the boiling point. Adjacent to this kettle and at the same height above the floor (33 inches) is a cement vat of the same size and shape as the cauldron. This vat holds the water used in rinsing the grapes after dipping, and is equipped with a drain pipe and fresh water supply. The dipping machine consists of the following parts. Two 22-inch prune-dipping baskets are hung at the ends of 3″ × 4″ pieces which are 5½ feet long and pivoted on two 4″ × 4″ pieces, which in turn are attached to a 6″ × 6″ upright piece and supported by 2″ × 4″ pieces, as shown in figure 2 section. The 6″ × 6″ upright pieces rest on a roller bearing pivot. The baskets are counterbalanced by boxes of sand. The end of each basket support carrying the sand box is connected to a pivoted handle so that the basket may be depressed into the lye solution or rinse water by merely raising this handle. The handle is also used in swinging the loaded basket from the loading chute to the lye kettle; from lye kettle to the rinsing vat, from the rinsing

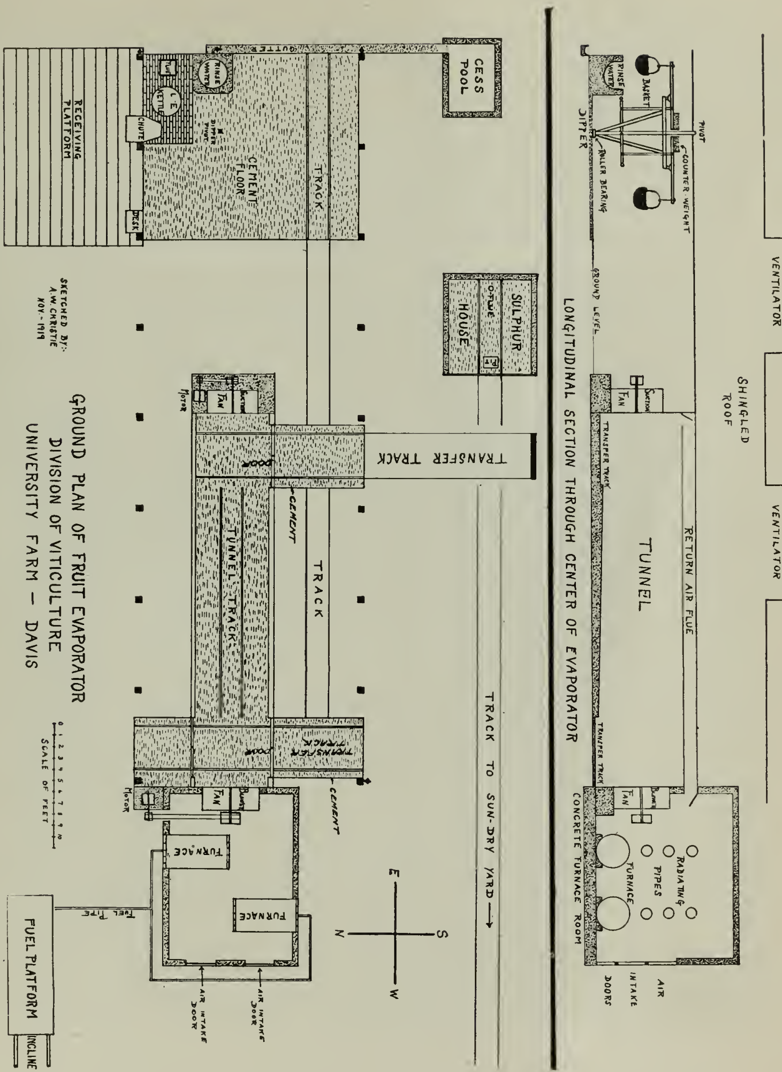

Fig. 2.—Longitudinal section and ground plan of University Farm evaporator as constructed and used during 1919 season.

vat to the tray loading table, and from this point back to the loading chute. This dipping machine is patterned closely after the "Sutter County Merry-Go-Round Dipper" used for many years for dipping Sultanina grapes before drying and may be purchased in complete form from manufacturers, although the outfit is not complicated and can be built locally. The ordinary prune dippers of various forms may be used successfully, but must be equipped for rinsing the dipped grapes. Continuous dipping machines for grapes are available.

A platform 16′ × 12′ and 2 feet high is placed outside the evaporator shed but adjacent to the dipping outfit for receiving the fresh grapes. A concrete sulfur house, 7 feet wide by 7½ feet high by 8 feet long, inside measurements, is located a short distance from the shed. It is equipped with tight-fitting folding doors; a 6-inch adjustable ventilator in roof; a sulfur pit, 8 inches deep and 8″ × 12″ in size, and tracks for drier cars. It will hold two loaded cars.

Thirteen wooden frame dry-yard trucks were used. The evaporator held eight cars when filled to capacity and each car held 42 trays of 35 pounds of grapes each, making a total of six tons of fresh grapes per charge. The frames on the trucks were placed at right angles to the tracks upon which the cars operate. This position of the frames makes each truck six feet wide and three feet long and therefore only one track is necessary in the tunnel. The transfer cars are of steel construction throughout and of the type used in evaporators in Fresno County in which raisins are dried for cap stemming. Both the evaporator and the transfer cars were very satisfactory, except for the difficulty in moving the cars because of the friction on the axles. Roller-bearing wheels would be much more desirable but are costly.

The trays are three feet square. Each side is constructed of one piece, 36″ × 1½″ × 1½″ and one piece, 33″ × ⅞″ × 1½″; each end consists of one piece, 36″ × ⅞″ × 1½″ and one piece, 33″ × ⅜″ × ⅞″. The tray is braced through the center by one piece, 33″ × ⅞″ × 1″, and one piece, 34″ × ⅜″ ⅞″. Most of the trays were made with screen bottoms held between the various pieces of shook listed above. (See fig. 9.) The most satisfactory trays were of the above construction for the frame but with narrow wooden slats substituted for the screen. Screen of ¼″ mesh is much better than that of ½″ mesh. It was found necessary to raise the height of the sides of the trays by nailing to them strips 1″ × 1½″ × 36″ in size in order to give sufficient space for passage of air.

(c) COURSE FOLLOWED BY GRAPES AT EVAPORATOR

The grapes were ordinarily treated as follows: The fresh grapes were unloaded at the receiving platform and weighed. They were then emptied into the chute from which they fell into the dipping basket. The basket was immersed in the boiling lye solution, which varied in strength, from ½ per cent to 3 per cent lye according to the variety of grapes. After 5 to 40 seconds' immersion in the lye solution, the time varying with the variety, the grapes were plunged into cold water to remove adhering lye. The basket of rinsed grapes was then transferred to an empty tray and the grapes spread evenly by hand. The loaded trays were stacked in two tiers of 21 trays each on a car. The loaded car was transferred to the sulfur house and exposed to sulfur fumes for about 30 minutes. In some cases sulfuring was omitted. The car of fruit then entered the tunnel at the end opposite the furnace room where the air was moister and 20 to 30 degrees cooler than at the furnace end. As each car of dried grapes

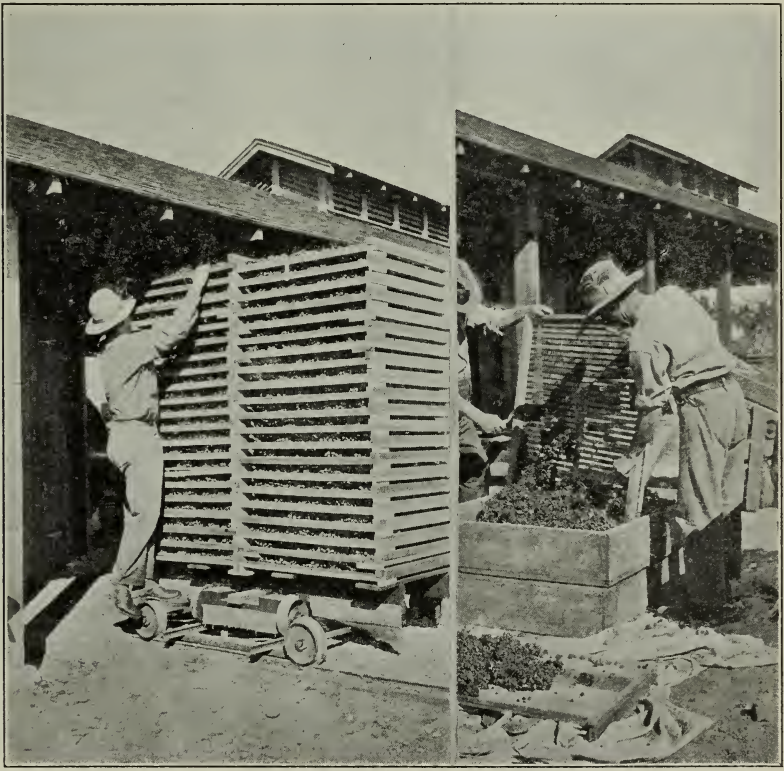

Fig. 3.—Evaporator car loaded with trays of freshly dipped grapes. Note transfer car beneath evaporator car. Unloading slat bottom tray at right.

was removed through the side door at the furnace end of the tunnel, the remaining cars were moved forward the length of one car, and a fresh car was inserted at the exhaust end. The dried grapes were allowed to cool and were then transferred to sacks for shipment without stemming.

All of the above steps were varied greatly during the various experiments.

(*d*) SUGGESTED REVISIONS IN PLAN OF UNIVERSITY FARM EVAPORATOR

The evaporator in its first form proved successful. However, the past season's experience showed that certain additions and changes are desirable in order to increase the efficiency of the plant and the convenience of operation. The sketches shown in figures 4 and 5 indicate the construction of an evaporator recommended to growers. It resembles the University Farm evaporator very closely in outline and appearance, but includes in its construction the modifications and additions noted below. Practically all of the suggested changes have been made and may be seen by those who wish to visit the University Farm at Davis.

1. *Furnace Room.*—One furnace, 10′ to 12′ long by 3′ in diameter, equipped with a medium-size air-blast distillate burner is sufficient. The furnace room should be of fire-proof construction, e.g., concrete, brick, or tile and should be about 14′ long by 8′ wide by 11′ high, inside dimensions. Attached to the furnace are nine lengths of 12-inch heavy gauge black iron pipe distributed as shown in figure 5, giving a total length of radiating pipe, including connections, of approximately 120 feet. The pipes are arranged in three tiers of three pipes each. The individual pieces are joined together vertically by return bends and horizontally by headers or T connections. A T connects the smokestack to the radiating pipe system. This is fitted with two dampers by means of which the gases of combustion may be allowed to flow out through the stack or into the furnace room as desired. This arrangement of pipes and dampers gives approximately three times the heating surface furnished by the first installation for one furnace and also makes it possible to use the gases of combustion directly in drying.

At each side of the furnace in the end wall of the furnace room is situated an air intake door. Each is one foot wide and one and a half feet high. Another air intake door of same size is located two feet above the furnace. All doors should be sliding to enable regulation of air intake. (See revised plan, fig. 5.) The evaporator now includes essentially these features.

2. *Connection of Furnace Room to Tunnel.*—No fan to be located between the furnace room and tunnel and the opening connecting the two to be of same size as cross section of tunnel; that is, 7 feet high by 6½ feet wide.

3. *Fan.*—The two disc fans of the present installation to be replaced by a top vertical discharge multivane fan with fan wheel

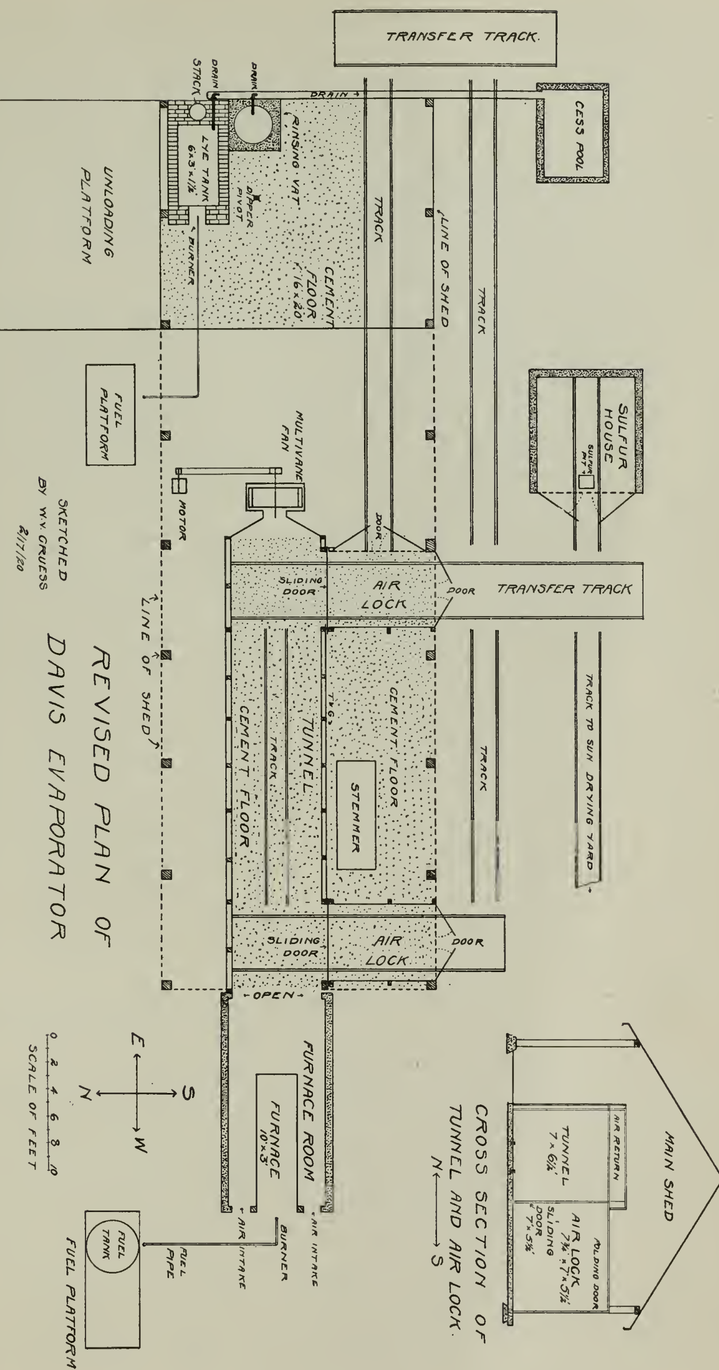

Fig. 4.—Revised plan of University Farm evaporator.

36 inches in diameter and connected to a 7½ horsepower motor by belt and pulleys to give about 300 r.p.m. The fan to be located at air exit end of tunnel. Intake of fan to be connected by sheet metal housing to tunnel outlet. The discharge of fan to be connected to return flue of tunnel and also arranged to discharge into the open air as shown in figure 5; these two connections to be equipped with adjustable dampers so that any proportion of the exhaust air may be returned to the furnace room or discharged into the open air. This fan has now been installed.

4. *Air Locks.*—During the past season considerable heated air was lost and drying was interrupted when the doors of the tunnel were opened to insert or remove cars, or to enter the tunnel to take observations on temperature, etc. It is, therefore, very desirable to build compartments at entrance and exit of the tunnel as shown in figure 4. In using the compartment at the entrance end of the tunnel the car of fresh fruit enters the compartment through the folding doors at the side of the compartment. The operator enters with the car and closes the doors. He then opens the sliding door connecting the air lock with the tunnel, places the car in the tunnel and closes the sliding door. Finished cars are removed in a similar manner. Practically no heated air is lost or cold air drawn in during the above operations.

The air lock for entrance of fresh fruit consists of a compartment 5½ feet wide, 7 feet high, and 7¾ feet long, inside dimensions. Two folding doors form the side of the air lock toward the dipping outfit and a second set of doors opens toward the sulfur house. The lock for removal of cars of dried fruit is of the same dimensions and construction, except that it is equipped with doors at the ends only. Both locks are constructed of 1″ × 4″ tongue and groove pine over a frame of 2″ × 4″ pine. These may now be seen in place at the University Farm.

5. *Dipping Tank.*—It was very difficult to maintain the lye solution at the boiling point during the 1919 season because of the small size of the dipping cauldron, 50 gallons, and necessity of using wood or coal instead of oil for fuel. The 50-gallon kettle has been replaced by a sheet metal tank 6′ long by 3′ wide by 1½′ deep mounted in a fire brick furnace equipped with a medium-size blast-type distillate burner. The above tank will hold about 200 gallons of liquid and presents a long surface to the furnace flame. The experience of others has proved that a furnace and dipping tank of this type can be maintained at the boiling point during continuous operation.

6. *Rinsing Vat.*—The present 50-gallon rinsing vat could be increased to 200 gallons in size to advantage. This would require less

frequent changing of rinse water. A sheet metal drain over the space between the dipping vat and the rinsing vat for return to the dipping vat of the lye solution which drips from the dipping basket would reduce the loss of lye solution.

7. *Track System.*—The track now located under the shed at the south side of the tunnel will be moved outside the shed and will

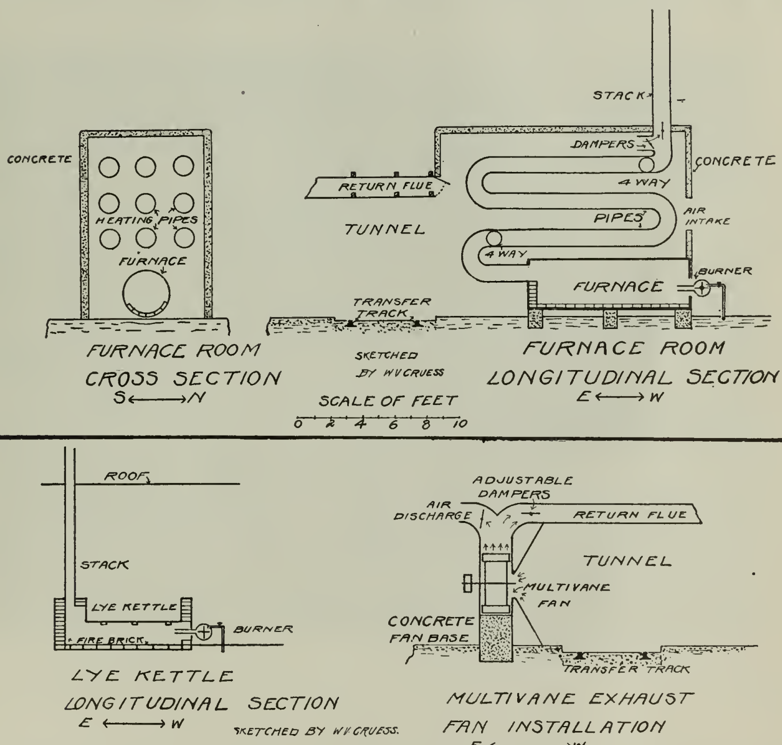

Fig. 5.—Sections showing fan connections, lye tank, and furnace room, of revised University Farm evaporator.

connect to two transfer tracks as shown in figure 4. This track will be continued to the west end of the shed where it will connect to a transfer track which in turn connects to the track between the dipping outfit and tunnel entrance. This arrangement will make it possible to move loaded and empty cars to and from the tunnel without interference.

8. *Observation Windows.*—Six or seven small port holes about one foot square have been cut in the north wall of the tunnel at such points that each car of fruit in the tunnel may be observed and samples removed. The windows are closed by air-tight doors.

9. *Double Walls for Tunnel.*—The first tunnel walls were made of one thickness, 1″ × 4″ T & G over 2″ × 4″ pine outside frame. The frame has been covered with T & G over building paper, to make the walls airtight and to reduce radiation losses.

10. *Tray Guides on Trucks.*—Difficulty was encountered during the past season in holding the trays on the trucks in a perfectly vertical position. Upright guides of 2″ × 4″ have been placed in the

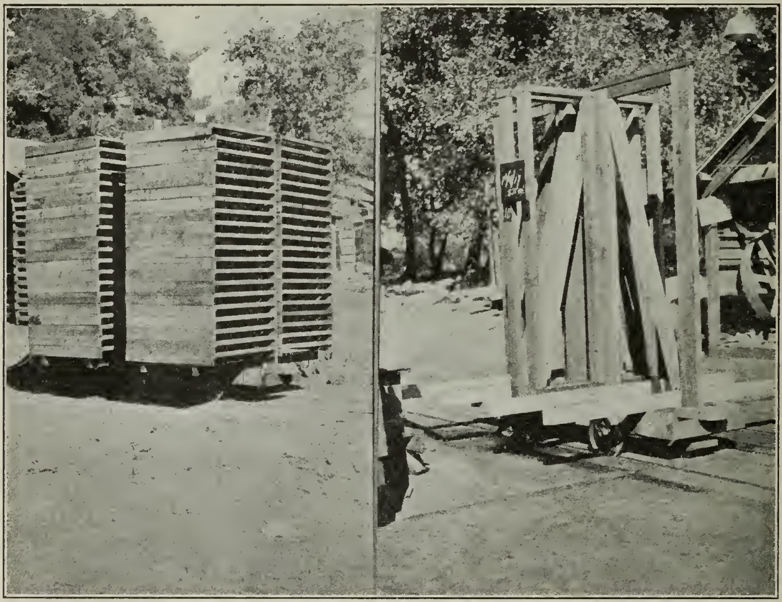

Fig. 6.—Photographs of an evaporator truck equipped with upright guide-posts for trays.

center of each car frame and the trays will be stacked against this frame. The tunnel is wide enough to permit this change. See figure 6 which illustrates such a car used in the Pearson evaporator.

11. *Trays.*—Most of the screen bottom trays will be converted into slat bottom trays by replacing the screens with narrow wooden slats placed about 3/8 of an inch apart. The sides of all trays will be increased in height by the addition of pieces 36″ × 1″ × 1½″ to trays not already so equipped.

12. *Air Baffles.*—To prevent the passage of heated air beneath the cars during the past season pieces of canvas were nailed to the car frames. These extended from the level of the track to the bottom of the cars. These will be replaced in part by two enclosed wooden platforms on the tunnel floor, one on each side of the tunnel track,

of such height that the frames of the trucks will barely clear them. These platforms will be closed so that the air will not be permitted to flow beneath the car frames between the tracks and walls of tunnel. The canvas will be retained on the car frame between the tracks only.

It is essential that all possible precautions be taken to force the air to flow over the trays. Air, like water, follows the channels of least resistance, and instead of flowing over the trays tends to follow all possible passages at the sides of the cars, beneath the trucks or above the topmost tray.

V. COST OF OPERATION

Because of the fact that the University Farm evaporator during the past season was employed in the drying of numerous small experimental lots of grapes, our cost of operation was abnormally high. *Therefore, due allowance must be made for this fact in considering our data on costs of operation given in the following summary:*

1. Total tons of fresh grapes handled at evaporator	52.18
2. Total tons of dry grapes handled at evaporator	15.65
3. Labor cost per fresh ton	$ 8.102
4. Labor cost per dry ton	$27.015
5. Labor cost of dipping per dry ton	$ 8.78
6. Labor cost of unloading trays per dry ton	$10.52
7. Labor cost of general work per dry ton	$ 5.69
8. Labor cost of night operator per dry ton	$ .63
9. Cost of fuel per green ton (stove distillate at 8c per gallon)	$ 6.23
10. Cost of fuel per dry ton (stove distillate at 8c per gallon)	$21.52
11. Cost of electric light and power per green ton of grapes	$ .50
12. Cost of electric light and power per dry ton of grapes	$ 1.73
13. Containers for dried product (second-hand barley sacks at 8c each), cost per ton of dry grapes	$ 2.00
14. Interest and depreciation at 10% (on $3500), cost per green ton	$ 7.71
15. Interest and depreciation at 10% (on $3500), cost per dry ton	$22.36
16. Total cost per green ton	$28.562
17. Total cost per dry ton	$74.620
18. Total cost per green ton, exclusive of depreciation	$20.852
19. Total cost per dry ton, exclusive of depreciation	$52.260

If the interest and depreciation are included in the cost of operation the total cost per dry pound of grapes was in excess of 3½c and per fresh pound over 1¼c. Because of our short operating season the item of interest and depreciation is excessively high. If it is omitted from the calculations the costs become approximately 2½c per dry pound and slightly over 1c per fresh pound. It is certain that by conducting the University Farm evaporating plant upon a commercial basis and by adopting the modifications in methods of operation that last season's experience have shown to be desirable, the costs given above could be very materially reduced.

IV. RESULTS OF INVESTIGATIONS

As many as possible of the different processes involved in the drying of grapes in the sun and in evaporators were investigated. A great deal of information was obtained, although time did not permit the completion of all the experiments undertaken nor the solution of all of the problems presented. At least one more season's work is necessary to obtain the data needed.

Because of the voluminous nature of the original data, even when condensed by tabulation, it is necessary to present the results in summarized form. Investigators or others who may be interested in a detailed study of our experimental results are invited to inspect the data filed in the projects in our office.

The results will be taken up as nearly as possible in the sequence in which the various evaporation processes occur.

(*a*) DIPPING

The dipping of grapes in a hot lye solution before drying has been practised for many years in the sun-drying of Sultanina (Thompson Seedless) grapes to hasten the rate of drying. Its use in the treatment of Muscat grapes, table grapes, and many varieties of wine grapes was thoroughly tested.

It was found that different varieties exhibited a most remarkable difference in their behavior in the dipping solution. Sultanina, Tokay, Emperor, Zalbalkanski, Palomino, Black Morocco, and Cornichon gave excellent results when dipped in a boiling solution of ½ per cent to 1 per cent lye followed by rinsing in water. The skins of these grapes were checked into numerous minute cracks extending from the stem toward the apex of the berries. Practically all berries on the bunch responded to the dipping and the checks were well distributed and uniform in size. Solutions stronger than 1 per cent lye tended to cause slipping of the skins of some of the berries. Of the grapes listed above, the Sultanina gave the best results, the berries of this variety requiring only 3 to 5 seconds' immersion in the boiling lye solution. Tokays required 10 to 15 seconds, and the checks were somewhat deeper and longer than those on the Sultanina. The same characteristics held for the other large varieties named above.

Most of the wine grape varieties, such as Petite Sirah, Zinfandel, Carignane, Alicante Bouschet, St. Macaire, Mondeuse, Crabbe's Black

Burgundy, Barbera, Valdepenas, Refosco, Lagrain, Gros Mansenc, Burger, Franken, and Johannesburg Riesling, Sauvignon Vert, Sauvignon Blanc, and West's White Prolific were very difficult to check by dipping. It was necessary with these varieties to use a dipping solution of 2 to 3 per cent lye (17 to 25 pounds of granular sodium hydroxid—soda lye—per 100 gallons of water) and to maintain this solution at the boiling point. Weak solutions had no apparent effect except to remove the bloom. Many driers of wine grapes became discouraged because of the difficulty in obtaining satisfactory results and dried their grapes without dipping, thereby greatly increasing the time necessary for drying. The secrets of success lie in using a lye dip of at least 2 per cent active lye and to keep the solution *actively* boiling. Even under these favorable conditions, it was found that from 20 to 40 seconds' time was necessary for the grape varieties listed above. These varieties developed deeper cracks than those given in the first list above. The cracks were unevenly distributed and tended to extend at right angles to the vertical axis of the grapes rather than parallel to that axis. Many berries became softened and deeply cracked while others on the same bunch exhibited no apparent effect of the lye. The berries of some varieties tended to shatter badly from the bunches. In spite of this defect, however, the fact that dipping shortened the time of drying by one half was held sufficient reason for dipping.

Muscat and Malaga grapes, because of their tough, thick skins, were the most difficult grapes of all to check by lye dipping. The berries tended to burst before the lye checked the skins. The cracks were deep and unevenly distributed. Nevertheless, dipping of these varieties is necessary for rapid drying. A 2 to 3 per cent solution of lye at 212° F. for 30 to 50 seconds was necessary for effective results.

It was found practically impossible to check the skins of eastern varieties such as Concord, Isabella, etc.

The effect of dipping on the appearance of the finished product is very noticeable. Dipping removes the natural bloom of the grapes and imparts a glossy appearance. Raisins from dipped grapes are more sticky than those from undipped grapes. The flavor is not materially affected unless the lye is not thoroughly removed by rinsing in clean water before drying. Where rinsing is not well done, the raisins will possess a distinct although not especially disagreeable "lye" flavor. Dipped grapes produce a raisin of sweeter taste than undipped because some of the grape acid is neutralized by the lye.

TABLE 1.—EFFECT OF DIPPING ON RATE OF EVAPORATION OF GRAPES

Burger grapes, No. 2739				Tokay grapes, No. 2737			
Time in hours	Temperature	Weight of grapes undipped, grams	Weight of grapes dipped, grams	Time in hours	Temperature	Weight of grapes undipped, grams	Weight of grapes dipped, grams
0	140° F.	1500	1500	0	145° F.	1200	1200
4.5	140° F.	1272	1038	2	145° F.	1145	935
6	140° F.	1192	853	6	145° F.	980	515
8	140° F.	1134	728	8.5	145° F.	924	422
9	140° F.	1082	633	10	145° F.	813	317
15.5	140° F.	902	408	12.5	145° F.	728	273
17	140° F.	802	363	16.5	145° F.	630	233
				19.5	145° F.	580	225
				23.5	145° F.	554	227
				32	145° F.	518	220
				38	145° F.	378	212
				40	145° F.	325	......

The dipping of the fresh grapes before drying is remarkable in its effect upon the rate of drying. Numerous tests upon the rate of drying of dipped and undipped grapes both in the evaporator and in the sun were made. Table 1 and the curves in figure 7 illustrate this point. The data of table 1 were obtained by drying dipped and undipped grapes on small screen-bottom trays in the laboratory evaporator at Berkeley. This evaporator is so constructed that a strong current of heated air is driven across the trays by means of a fan. Because of the high velocity of the air, the rate of drying was rapid. This small evaporator is very useful for experimental purposes because of the fact that the temperature and humidity of the air used in drying may be easily regulated.

The results shown in figure 7, curve II, were obtained by weighing dipped and undipped lots of Carignane grapes during the drying of these grapes on field trays in the sun.

From the table and curves it may be seen that the dipped Tokay grapes were thoroughly dried in 16½ hours while the undipped grapes of the same variety were not sufficiently dried after 40 hours. Dipping in this case more than doubled the speed of drying. Similar results were obtained with Burger grapes and several other varieties in laboratory tests.

In the sun-drying tests the dipped grapes lost 65 per cent of their weight and were sufficiently dried at 20 days, while 33 days were required for the undipped grapes to reach the same degree of dryness. Dipping in this case reduced the time of drying by approximately one third.

In addition to the experimental results given above, measurements were made to determine the quantity of lye used in dipping different varieties of grapes. It was found that varieties such as Petite Sirah,

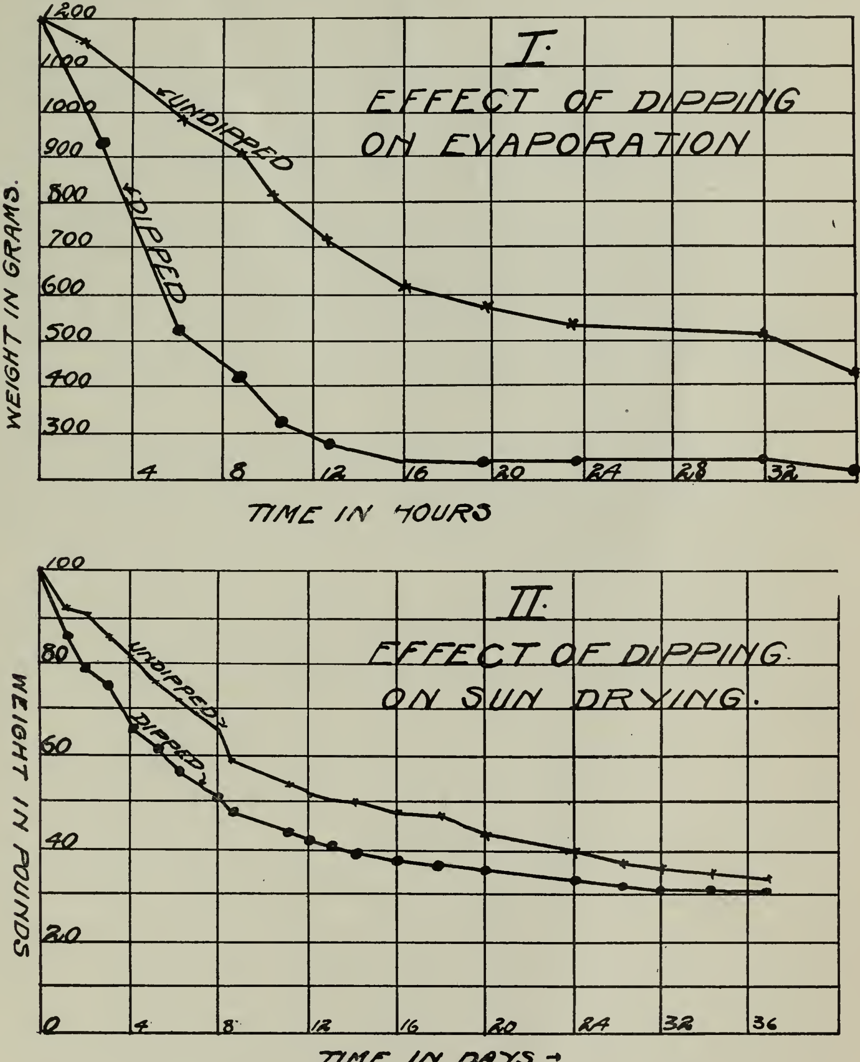

Fig. 7.—I, Curves illustrating effect of dipping on rate of drying of Tokay grapes in an evaporator. II, Effect of dipping on rate of drying Carignane grapes in sun.

Semillon, and Zinfandel, with tough skins, required about five pounds of lye per ton of fresh grapes. Of this quantity about one pound was lost in the rinsing water while the remaining four pounds represent lye neutralized by the grapes when the grapes were immersed for 30 seconds in the lye.

Observations were also made upon the amount of lye lost in dipping Petite Sirah grapes at the Pearson evaporator at Yountville. The grapes were immersed in lye of 3.2 per cent sodium hydroxid for 20 seconds. After dipping 2800 pounds of grapes and adding water to the vat to replace that lost mechanically and by evaporation, it was found that the lye concentration had decreased .6 per cent. This corresponds to a loss of 14 pounds of lye per ton of grapes. Of this, one sixth, or 2.3 pounds, was neutralized by the grapes and the remainder, 11.7 pounds, was lost in the rinsing vat. Based upon a dipping period of 20 seconds, the average amount of lye neutralized by such varieties as Petite Sirah at Davis and at the Pearson evaporator was approximately 2.5 pounds per ton of fresh grapes. Theoretically this should reduce the acidity of the grapes approximately .25 per cent.

The smaller loss of lye in rinsing in our tests was probably due to the fact that the dipped grapes were more thoroughly drained before rinsing and that a stronger lye solution was used at the Pearson plant. Our tests demonstrated that the loss of lye in rinsing was greater with the stronger lye solutions.

Thin-skinned varieties, such as the Sultanina, required about 1¾ pounds of lye per fresh ton of grapes. Of this, about half a pound was lost in the rinse water and 1¼ pounds was neutralized by the grapes.

Grapes are coated with a waxy bloom which disappears in the lye dip. It is probable that this substance neutralizes considerable quantities of the lye because it is a wellknown fact that some fruit waxes possess the power of neutralizing lye.

It was observed that shrivelled over-ripe grapes as well as grapes that had wilted by standing in boxes several days during warm weather were much more difficult if not impossible to check in the lye solution, thereby necessitating a longer time to dry. Grapes that had stood several days in lug boxes and had become moldy or had started to ferment, softened and shattered badly from the bunches in dipping. For these reasons grapes should be dipped as soon as possible after picking.

A record of the labor cost of dipping, spreading and stacking the trays of grapes was kept for the entire season. The following table summarizes some of the results obtained.

TABLE 2.—LABOR RECORD OF DIPPING AND SPREADING GRAPES

Variety	Pounds dipped per hour	Labor cost per fresh ton	Labor cost per dry ton
Sultanina	2166	$1.49	$5.08
Tokay	1808	1.79	6.09
Muscat	1241	2.61	8.19
Gros Mansenc	1151	2.81	8.31
Zinfandel	1073	3.02	10.24
Petite Sirah	1005	3.22	10.47
Average for season, all varieties		$2.62	$8.78

Because of the fact that much of the work was done with small experimental lots the labor costs of dipping were abnormally high and it should be possible under average commercial conditions to greatly reduce the costs given in table 2. The figures also include the cost of spreading the fruit and stacking the trays on the drier trucks. Two men were used in operating the dipper and two in spreading and stacking trays. Therefore, to obtain a fair idea of the labor cost of dipping only, the above figures should be divided by two, thus giving an average labor cost of dipping for the season of $1.31 per fresh ton or $4.39 per dry ton, or $0.00214 (⅕c) per dry pound.

About five to six gallons of stove distillate per hour at 6c to 8c per gallon was required to maintain a tank containing approximately 400 gallons of lye solution at the boiling point at the Pearson plant. The total cost of fuel per hour varied from 30c to 48c. This corresponds to a cost of approximately 15c to 24c per fresh ton of Petite Sirah or similar grapes.

(*b*) SUN-DRYING VERSUS EVAPORATION

A very important question before the fruit growers of California concerns the relative merits of drying fruit in the sun and in evaporators. Which of these two methods will prove the more profitable to the growers depends upon several factors, the most important of which are: (1) relative yields of dry product, (2) quality of dry product, (3) cost of drying, (4) initial investment and depreciation.

A number of experiments were undertaken at Davis to compare the yields of several varieties of grapes dried in the sun with lots of the same varieties dried in the evaporator. It is to be regretted that the results were not absolutely conclusive. The difference in yield by the two methods is so small that a large number of tests will be necessary to definitely solve the problem. The results of the past season's tests are summarized in the following table:

Table 3.—Summary of Results of Yields of Moisture-Free Product per 100 Pounds Fresh Grapes

	By sun-drying, pounds	By evaporator, pounds
Muscat grapes	25.31	25.93
Sultanina grapes	27.79	26.71
Tokay grapes	24.10	23.51
Zinfandel grapes	35.02	27.59
Lagrain grapes	29.88	33.11
Carignane grapes	27.42	23.60
Semillon grapes	27.93	28.35
Average, all varieties	28.26	25.22

An examination of the two tables indicates that Semillon, Lagrain, and Muscat varieties gave higher yields in the evaporator, while the Carignane, Zinfandel, Tokay, and Sultanina varieties gave higher yields by sun-drying. Averages of all tests gave a slightly higher yield for the sun-drying method.

The only conclusion which seems warranted is that our experiments indicate little difference in the yields of moisture-free product obtained by sun-drying and evaporation. If these results are confirmed by future tests it will mean that the choice between the two methods will have to be made on relative quality of the finished product, cost of operation, and prices received for the dried fruit, rather than upon comparative yields.

The above conclusions are based upon the relative yields of moisture-free product. This is obtained by means of a calculation based upon the drying ratio and moisture content of the finished product. It affords the only accurate basis of comparison. However, a comparison of an average of the drying ratios given in table 3 is of interest. The average drying ratio for sun-dried grapes was 3.04 as against 3.21 for the evaporated grapes, a difference of .17 or 5.44 per cent greater yield in favor of the sun-drying. This would indicate that there was at Davis a tendency to dry the grapes in the evaporator to a lower moisture content with consequent lower yield of dried product. The fact that the degree of drying can be accurately regulated in the evaporator is a strong point in its favor. More will be said about the moisture content of dried grapes later.

White grapes dried in the evaporator were lighter in color than the same grapes dried in the sun and to produce a raisin of very light color a much shorter time of sulfuring was required for the grapes dried in the evaporator. Sultanina grapes sulfured for a half hour and dried in the evaporator were as light in color as the same variety sulfured for three hours and dried in the sun.

Evaporated grapes retained more of the fresh grape flavor and developed much less of a caramel or "raisin" flavor than the same varieties of grapes dried in the sun. Muscat grapes dried in the evaporator possessed a pronounced fresh Muscat flavor and were more acid or tart to the taste than sun-dried Muscats. The color and flavor of sun-dried Muscat raisins has been firmly established in the mind of the consuming public by extensive national advertising. Therefore, although the flavor of the Muscat raisin made by evaporation more nearly resembles that of the fresh fruit, this difference in flavor from that of the sun-dried article makes it doubtful whether its merits would be appreciated by the consumer unless it were well advertised. Should over-production of Muscat raisins ever occur, the drying of a part of the crop in artificial evaporators in order to produce a raisin of special quality might well be considered.

Red-wine grapes, such as Zinfandel and Petite Sirah, dried in the sun were apparently as deep in color and of as good quality as the same varieties dried in the evaporator, but when the color and flavor of the juices obtained by pressing the dried grapes after soaking in water were compared the juice from the evaporated grapes was deep red in color and of pleasing flavor while that from the sun-dried grapes was of a brown color and poorer in flavor. These observations are confirmed by tests made upon red-wine grapes dried in the sun at the Kearney Vineyard several years ago. It would appear that sunlight injures the color or that chemical changes taking place at the low temperatures of sun drying may cause oxidation and browning of the color. If dried wine grapes are exported to foreign countries for wine making the evaporated product will be found much superior to the sun-dried.

The relative costs of evaporation and sun-drying have not been definitely determined by one season's operation, because the operation of grape evaporators during the past season was largely experimental in nature and methods were not standardized. Our experience would indicate that the cost of evaporating dipped grapes is no greater than in sun-drying except for the cost of fuel and power. The labor cost is at least no greater for evaporation and is probably less than for sun-drying dipped grapes. The labor cost involved in drying grapes on field trays in the vineyard is doubtless less than that necessary in evaporating, but the higher quality and price of evaporated wine grapes more than compensate for the extra cost of evaporation. This fact was well established during the 1919 season when a difference of as much as 4c per pound existed in favor of the evaporated grapes.

The preference for the evaporated product is said to be even more pronounced at the present time than it was during the past fall.

The fact that drying in the sun incurs danger of loss by rain damage is another reason for favoring evaporation.

(c) SULFURING

Grapes of several different varieties were sulfured for various lengths of time and were subsequently dried in the sun or in the evaporator. It was found that less than half as long a period of exposure to sulfur fumes was necessary for the grapes dried in the evaporator. This is probably because the period of drying in the evaporator is so much shorter than that necessary for sun-drying and because the higher temperature of the evaporator reduces the tendency of the fruit to darken.

Red-wine grapes which were dried in the sun without sulfuring gave a juice of brown color on extraction with water; but the same varieties of grapes which were sulfured for one hour or longer before drying in the sun gave a water extract of red color and pleasing flavor. Therefore, it is advised that red wine grapes that are to be dried in the sun be sulfured for about one hour before drying.

It was found that grapes dried in the evaporator or sun after three hours' sulfuring fermented readily when ground and mixed with water; that is, this amount of sulfuring was not sufficient to prevent the use of such grapes for vinegar making in the United States or for wine making when exported to foreign markets.

The color of all grapes dried in the evaporator was improved by a short sulfuring. Thirty minutes' exposure to sulfur fumes was sufficient for most white varieties and for Tokay and other grapes of pink color. Fifteen to twenty minutes improved the color of red-wine varieties, although perfectly satisfactory results are obtained with such grapes without sulfuring. Sulfuring appeared to injure the flavor even when used for a very short length of time, and it is doubtful whether the improved color compensates for the injury to flavor.

As noted elsewhere in this report, unprotected screen trays became badly corroded by sulfur fumes and the zinc salts so formed imparted a metallic flavor to the fruit. The use of slat bottom trays would solve this problem.

The results of our Davis experiments indicate that slightly greater yields of dried product are obtained if the grapes are sulfured before sun-drying or evaporation. Increased yields were obtained in a large number of experiments, but were relatively small in amount. Further tests must be made to confirm the results of the past season. The sulfurous acid absorbed by the fruit from the burning sulfur perhaps reduces loss by oxidation during drying and this might account for the increased yields observed. Further tests are necessary on this point.

Sulfuring is not necessary and is not recommended as a general practise in drying wine grapes.

(*d*) EFFECT OF TEMPERATURE ON QUALITY AND RATE OF DRYING

Theoretically, the rate of drying is directly proportional to the temperature, inversely proportional to the humidity, and proportional to the square root of the air velocity. These principles hold for the evaporation of water from a free surface.

Tests were first made in the laboratory to determine the effect of temperature on the rate of drying. The air velocity and other conditions were identical in all cases; only the temperature being varied. The following table and curves give the results of the tests made with Tokay grapes. Similar results were obtained with Alicante Bouschet grapes.

TABLE 4.—EFFECT OF TEMPERATURE ON RATE OF DRYING OF TOKAY GRAPES

140° F.–145° F.		160° F.–165° F.		190° F.–200° F.	
Time in hours	Weight in grams	Time in hours	Weight in grams	Time in hours	Weight in grams
0	2000	0	2000	0	2000
6	980	4	1100	3	850
10	585	9	605	5.5	565
16	520	14	440	7.5	485
20	500				
25	498				
29	480				

In large-scale experiments made by one of the authors* dipped Alicante Bouschet grapes were dried in six hours at 190° F., whereas sixteen hours' time was required to dry the same variety of grapes at 160° F.

The grapes dried at 190° F. in the large-scale tests at Yountville were dried in recirculated air of relatively high humidity. They appeared to be of equal quality in all respects to the grapes of the same variety evaporated at 160° F. Alicante Bouschet grapes dried

* A. W. Christie, in coöperation with J. W. Pearson and G. B. Ridley in the Pearson evaporator at Yountville.

in the small laboratory evaporator at 190° F. appeared to be of equal quality to those dried at 145° F. and 165° F., although when the grapes were left in the evaporator for several hours at 190° F. to 200° F. after becoming dry, a noticeable caramelized flavor developed. Tokay grapes developed the caramelized flavor more rapidly than did the Alicante Bouschet and exhibited this flavor to an appreciable degree even when removed from the evaporator as soon as sufficiently dry. The tests indicate, however, that temperatures of 190° F. to 200° F. under certain conditions may be safely used for Alicante Bouschet grapes and probably for other red-wine grapes. Recent analyses of the above lots of dried grapes show that a great deal of sugar was lost by action of heat at 190° F.

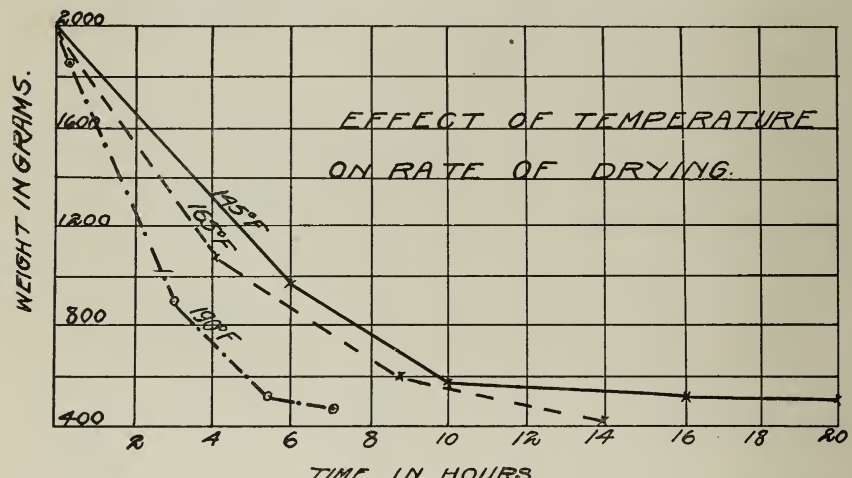

Fig. 8.—Curves illustrating the comparative rates of drying of Tokay grapes at three different temperatures.

(*e*) EFFECT OF CONSTRUCTION OF TRAYS

Most of the trays used in our experiments consisted of a wooden frame, 3′ × 3′, with a wire-screen bottom. Screens of ½, ⅓ and ¼ inch mesh were used. In addition to the screen-bottom trays a few trays were constructed with slat bottoms. The slats were about ½ by ⅜ inch in size and were placed about ⅜ of an inch apart. The accompanying figure illustrates the construction of these trays.

The framework of each tray consisted of:

2 pieces, 36″ × 1½″ × 1½″;
2 pieces, 36″ × ⅞″ × 1½″;
2 pieces, 33″ × ⅞″ × 1½″;
2 pieces, 33″ × ⅞″ × ⅜″;
1 piece, 33″ × ⅞″ × 1″; and
1 piece, 34″ × ⅜″ × ⅞″.

The 36″ × 1½″ × 1½″ pieces over pieces 33″ × ⅞″ × 1½″ formed the sides of the trays. These trays are the standard trays used at Fresno for drying raisins preliminary to cap stemming. It was found that the trays were not deep enough for grape varieties producing large bunches. Therefore, strips ⅞″ × 1½″ were nailed to the side strips to increase the height of the sides of each tray sufficiently for the bottoms of the trays to clear the bunches of grapes on the tray beneath. This gives a distance of 3 inches between screens, a space sufficient to permit free circulation of air and rapid and even drying.

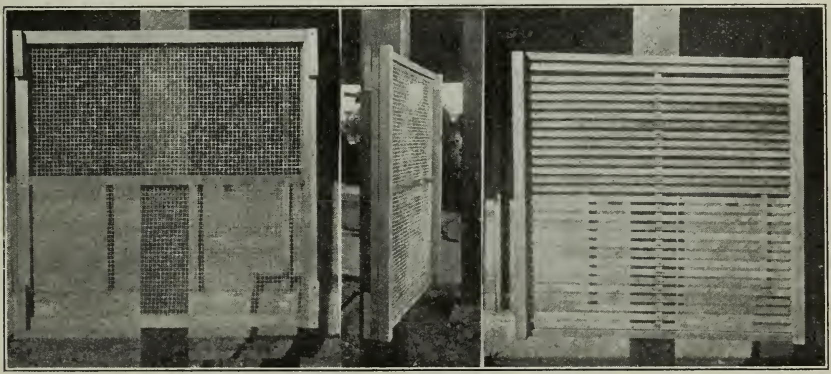

Fig. 9.—Photographs of screen bottom and slat bottom trays used in experiments at Davis. Trays are 3′ × 3′ in size.

Several serious objections to screen trays were encountered. The most serious was the tenacity with which the dried grapes adhered to the screen. The time of two or three men was needed to scrape the dried grapes from the trays whenever the evaporator was operated to full capacity. Users of other evaporators experienced the same difficulty, except where the grapes were dried without dipping. The juice from dipped grapes dried to a thick syrup at the point of contact of the berries and screen, thus cementing the fruit firmly to the trays. The vigorous scraping necessary to remove the fruit was severe on the wire screens and wooden frames of the trays; many of the trays became more or less weakened in one season's use on this account.

Where the grapes were sulfured the sulfurous acid generated by the burning sulfur attacked the zinc coating of the wire screens to such an extent that soluble zinc salts were formed in sufficient quantity to impart a metallic taste to the fruit.

Paraffine was tested as a coating for the trays. It was melted and applied to the screens with a brush. It protected the screen fairly well against corrosion, but caused the dried fruit to adhere to the screen even more tightly than where no paraffine was used. Asphalt and Gilsonite base paints and other special paints and varnishes either became soft and adhered to the fruit in the evaporator or became brittle and chipped off the screen during removal of the dried fruit from the trays. The authors are still searching for a suitable tray coating and have obtained several promising materials.

The rates of drying for grapes of several varieties on screen and on slat-bottom trays were compared by placing grapes on slat-bottom trays on cars loaded with screen trays containing the same variety of grapes. No difference in the rates of drying could be noticed. It was found, however, that the dried grapes were removed with great ease from the slat-bottom trays, there being practically no tendency to stick. Furthermore, these trays are rigid and retain their shape without sagging. There is, of course, no formation of metallic salts or corrosion of the trays by the action of sulfur fumes. Slat-bottom trays may be constructed at less cost than screen trays.

Trays with solid wooden bottoms of the type ordinarily used in sun-drying were compared with screen-bottom trays to determine the relative rates of drying on each. This is an important point because many grape growers already possess ordinary field trays and naturally wish to make use of them if they construct an evaporator. A test was first made in a commercial evaporator in which the air-blast rises vertically from a fan. In this evaporator the fruit (apricots) dried only one half as rapidly on the solid wooden bottom trays as on the screen trays. In our small laboratory evaporator, however, the tests were repeated with grapes and the use of a horizontal blast of air; that is, the heated air was blown across the trays. Five different varieties of grapes were tested. The different trays were of exactly the same length, breadth and depth, the only difference being in the construction of the tray bottoms.

The rate of drying in the case of the Muscat and Tokay grapes was practically as rapid on the wooden trays as on the screen trays. Burger grapes dried somewhat more rapidly on screen than on wood, although the difference was not very pronounced. This indicates that the ordinary solid bottom sun-drying trays can be successfully used in an evaporator where a horizontal air blast is employed providing the trays are separated by blocks or cleats to permit an ample flow of air.

(*f*) COMPARISON OF GRAVITY AND AIR-BLAST BURNERS

Two furnaces, each consisting of an old boiler shell 6 feet long by 3 feet in diameter connected to approximately 40 feet of 12-inch pipe were installed in the furnace room of the evaporator at Davis. In one of these was placed a medium-size air-blast burner and in the second furnace a large-size gravity burner. Except in very cold weather, it was found possible to maintain the air entering the evaporator at 140° F. to 145° F., using either burner alone. When the

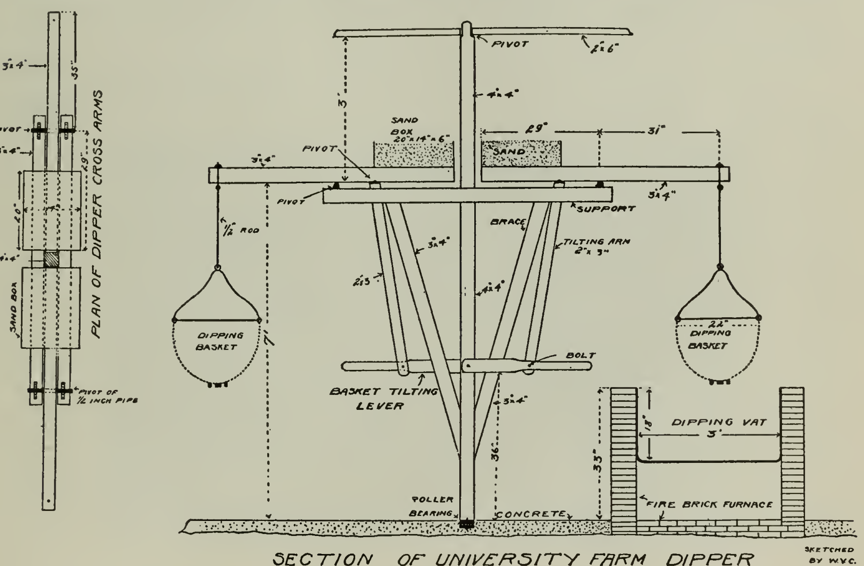

Fig. 10.—Sketch of dipping machine used at University Farm evaporator, 1919.

exhaust air was allowed to escape freely from the tunnel outlet, practically the full capacity of one burner was required to maintain the evaporator above 140° F., but when a large portion of the air was recirculated it was possible to maintain this temperature by using the air-blast burner at one half to two thirds capacity.

The air-blast burner was somewhat more efficient than the gravity burner for the reason that the latter gave incomplete combustion of the fuel. This fact was indicated by the black smoke which issued from the stack of the gravity burner furnace and by the large accumulation of soot in the radiating pipes. It was found necessary to seal the joints of the radiating pipes of this furnace with fire cement to prevent the soot from entering the tunnel with the heated air and causing blackening of the fruit. The air-blast burner on the other hand produced no soot; in fact, it was found possible to pass all the products of combustion of this furnace through the drying tunnel without injury to the grapes.

The gravity burner tended to heat the furnace walls less uniformly than did the air-blast burner. The flame of the latter extended throughout the entire length of the furnace, whereas that of the gravity burner was more localized and most intense immediately above the burner. An air-blast burner has another advantage in that a full flame is obtained immediately on lighting the burner, whereas at least a half hour is required to bring the gravity burner to full capacity.

In spite of these defects the gravity burner was found to be fairly satisfactory. It could be used successfully in localities where electric power is not available for the operation of an air-blast burner. It is cheap, easily installed, and simple in operation.

Our results demonstrated that one blast burner is sufficient for an evaporator of this size provided a large proportion of the air is recirculated. The furnaces were only six feet in length. One furnace ten or twelve feet long would be much more satisfactory because the flame of the air-blast burner often extended beyond the furnace into the radiating pipes. Only 40 feet of radiating pipe was used on each furnace. At least twice this amount should have been installed in order to reduce stack losses of heat to a minimum. By constructing the furnace according to these suggestions and eliminating one furnace it would be possible to greatly reduce the size and cost of the air-heating room. (See revised plans for further details.)

(*g*) COMPARISON OF DISC AND MULTIVANE FANS

No direct comparison of these two types of fans was made, but the rate of air flow through a large tunnel equipped with the multivane type of fan was determined and compared with the results of similar readings made upon the University Farm evaporator which was equipped with a disc fan.

Our drying tunnel was approximately 33 feet long and $6\frac{1}{2} \times 7$ feet in cross section. The rate of air flow over the trays on the last car when the tunnel was filled with loaded cars varied from 100 to 350 feet per minute. The average was approximately 220 feet per minute.

The drying tunnel of an evaporator in Napa County which was used for comparison was approximately 68 feet long and of about the same cross section as our evaporator. In this evaporator a multivane fan was operated at such speed as to deliver 18,000 cubic feet per minute (catalog rating), actual delivery 12,500 cubic feet per minute with loaded tunnel. (The disc fan was rated at 25,000 cubic feet per mnute.) When approximately 60 feet of the larger drying tunnel's length was filled with loaded cars the rate of air flow over the trays on the last car was approximately 420 feet per minute. The multivane fan operated against approximately double the resistance of the disc fan because the loaded tunnel was twice as long. In spite of this greater resistance the multivane fan gave a much greater rate of air flow; a fact which accounts for the more rapid rate of drying in this evaporator.

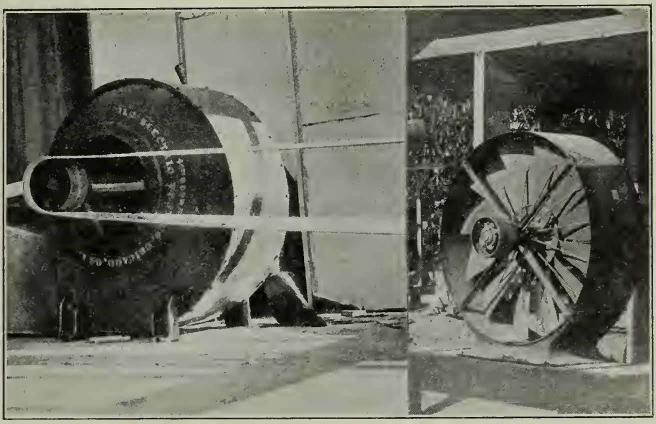

Fig. 11.—Multivane fan on left; disc fan on right.

These observations were not extensive, but nevertheless clearly indicate the great superiority of the multivane fan over the disc fan. The former is considerably more expensive than the latter but the difference in price is more than compensated for by the advantages of the multivane type. In addition to causing more rapid drying, it permits the use of longer tunnels, and thus makes possible a more complete utilization of the moisture-absorbing power of the air.

It is our opinion that the ideal ventilating system for an evaporator would be a multivane exhaust fan so arranged in relation to the air-heating system and air-return flue that the heated air may be drawn by the fan over the trays by suction, and any desired proportion of this exhaust air returned to the furnace room to be mixed with fresh air and recirculated.

This would combine the advantages of recirculation and humidity control with that of an exhaust fan of the multivane type.

The planing mill exhaust-type of fan, which is a more powerful type than the multivane, has been used successfully by a commercial evaporating company. This type of fan requires for operation considerably more power than the multivane fan of the same rating. It remains to be seen whether the planing mill exhauster will demonstrate advantages which will compensate for this greater cost for power.

(*h*) EXHAUST VERSUS POSITIVE BLAST FAN

The evaporator at Davis was equipped with a 60-inch disc fan at the furnace end of the tunnel. This was connected to a 7½ h.p. electric motor and was operated at such speed as to deliver theoretically 25,000 cubic feet of air per minute (catalog rating). At the outlet end of the tunnel was located a 54-inch disc fan, which could be used as a suction or exhaust fan at such speed that 25,000 cubic feet of air per minute should theoretically (catalog rating) have been drawn through the tunnel. As a matter of fact the actual amount of air delivered varied from about 10,000 cubic feet to 15,000 cubic feet per minute with each fan.

The evaporator was operated experimentally for a period of several days with the suction fan or the blast fan only. The conditions in the experiments being similar in other respects, the rate of drying of Tokay grapes was used as a basis for comparison. The following table summarizes the more important results obtained.

TABLE 5.—COMPARISON OF SUCTION AND POSITIVE BLAST FANS

	Positive blast fan I	Suction fan II
1. Fuel consumption, gallons per hour	7.50	8.8
2. Average temperature of air at furnace end of tunnel	133.4° F.	138.02° F.
3. Average temperature of outside air	67.7° F.	67.3° F.
4. Average increase of temperature	65.7° F.	70.72° F.
5. Humidity at furnace end of tunnel	3%	7%
6. Time to dry tokay grapes, hours	73	37.5
7. Average rate of air flow at end of tunnel, feet per minute	180	198
8. Relative efficiency based on time of drying and fuel consumption, test II taken as 100	60.22%	100%

The data given in the above table indicate that the suction fan is much more satisfactory and efficient than the positive blast fan. The slightly higher temperature of the air and the slightly greater rate of air flow probably accounts for the more rapid rate of drying with the suction fan.

In addition to more rapid drying, the suction fan appeared to cause the grapes to dry more evenly. However, too few observations were made upon this point to determine conclusively whether the difference was appreciable.

From the results of the above tests it would appear that evaporators equipped with the disc type of fan should make use of this fan as a suction fan rather than as a positive blower. It can not be stated whether the same relation holds true for other types of fans such as the multivane and mill exhaust fans.

(*i*) RECIRCULATION OF AIR

The evaporator was of such construction that any proportion of the air, after its passage through the tunnel, could be returned to the furnace room to be reheated and recirculated. A description of the recirculation system will be found in the plans and specifications.

In order to determine the relative rates of drying and relative fuel efficiency three tests were made. In one of these tests, the positive blast fan was used with outlet of tunnel completely opened and return air flue closed so that none of the air was recirculated. In another test, the tunnel outlet was closed to such a point that the air outlet was approximately three inches wide and seven feet long. The return air flue was opened as completely as possible, permitting a large proportion of the air (approximately 75%) to recirculate. In the third test, both the tunnel outlet and the return flue were left completely open. This permitted the recirculation of a smaller proportion of the air than in the second test. A great many observations on the rate of air flow, humidity, and rates of drying were made, but only the more essential results are given in table 6 on page 460.

In addition to the data given on rates of drying, it may be stated that Carignane grapes were dried in the first test in 20 hours and the maximum time required for any variety in this test was 33 hours. In the second test, the minimum time of drying was 46 hours and the maximum 73 hours; while in the third, 58 and 68 hours' time, respectively, were required.

Of the conditions existing in the evaporator during these three tests the temperature variation was the factor which would affect the rates of drying to the greatest degree. The fact that it was possible to maintain a higher temperature with the same fuel consumption during recirculation accounts for the greater efficiency of this method. The figures would indicate that the saving in fuel by use of recirculation was approximately 41%, basing this calculation upon a comparison of the first and second tests.

TABLE 6.—EFFECT OF RECIRCULATION ON FUEL EFFICIENCY AND RATE OF DRYING

Observation	Recirculation, Tunnel outlet nearly closed. I	No recirculation. Blast fan. II	Recirculation. Tunnel outlet completely open. III
1. Average fuel consumption per hour, gallons	7.57	7.50	6
2. Average temperature of air at furnace end of tunnel	141.1° F.	133.4° F.	127.4° F.
3. Average temperature of outside air	65.5° F.	67.7° F.	71.1° F.
4. Average increase in temperature of air	75.6° F.	65.7° F.	56.3° F.
5. Volume of air passing through tunnel, cubic feet per minute (approximate)	12,800	12,800	12,800
6. Humidity of air at furnace end of tunnel	10%	3%	7%
7. Average time required to dry grapes of same lot, hours	27.5	47	58.6
8. Fuel required to dry six tons of grapes, gallons	208	352	351
9. Relative efficiency based on time of drying and fuel consumption (test I taken as 100)	100%	59.14%	59.30%

Small-scale tests in the laboratory evaporator confirmed these observations. It was found that the burning of only about one half as much gas was necessary to maintain a given temperature when most of the air was recirculated. In these experiments it was practically impossible to over-dry grapes when most of the air was recirculated. The grapes dried to a certain moisture content and remained at that degree of dryness even when the evaporator was operated for a number of hours after this condition was reached. This indicates that it is possible to control the moisture content of the finished product by accurate control of the proportion of recirculated air. The importance of this fact can not be overemphasized, because it is very difficult to judge by observation of the grapes in the evaporator, whether they are sufficiently dry. The tendency of the beginner is to over-dry, which results in a low yield of inferior fruit.

These results were further confirmed by experiments made with a large commercial evaporator at Yountville.* Similar observations have been made by T. I. Casey and other manufacturers and users of evaporators equipped with the recirculation system.

A third advantage of recirculation claimed by Mr. Paul F. Nichols of the United States Department of Agriculture is that higher temperatures of drying may be used without injury to the fruit, if recirculation of the air is employed. Our own preliminary experiments indicate this to be true, but our investigations on this point have not been extensive enough to warrant definite conclusions.

We wish, therefore, to repeat a statement made earlier in this publication, viz., that the prospective purchaser or builder make certain that the evaporator shall be so constructed that any proportion of the air used in drying may be recirculated.

(*j*) DIRECT USE OF GASES OF COMBUSTION IN DRYING

In most evaporators a large amount of heat is lost in the gases leaving the smoke stack. It is evident that this loss could be eliminated if these gases may be passed through the evaporator after mixing with a sufficient quantity of outside air to give the desired temperature. This method has been used for many years in the drying of garbage and more recently in drying kelp (sea weed). Until recently, it had not been applied to the drying of fruits, because of the difficulty in eliminating all soot, smoke, and disagreeable odors in the burning of the fuels heretofore in use. It has been found during the past two or three years, however, that the products of combustion of natural gas may be used directly in the drying of fruits without injury to the quality of the dried product. At least three different types of evaporators are now successfully using this fuel in the above way.

More recently, improvements in the design of air-blast burners using stove distillate, have made possible such complete combustion of this fuel that the gases of combustion do not affect the flavor, odor, or color of the fruit. In one evaporator, in which this method has been highly developed, the fuel is burned in a long arched firebrick furnace in which is used a special form of air-blast burner. The furnace opens directly into the flue leading to the fan. This flue is fitted with a cold-air intake. By regulation of the size of this intake the mixed air and gases of combustion are given the desired temperature before they reach the fan. The furnace gases may during the

* These tests were made in the Pearson evaporator in coöperation with Messrs. Pearson and Ridley.

time necessary to heat the furnace be diverted into a smoke stack. This is necessary because a cold furnace prevents complete combustion.

It was found that grapes and apples could be dried in this type of evaporator without injury to quality from soot or fumes. The efficiency of this method in heating air is remarkable, tests showing that over 98% of the heat liberated in the combustion of the fuel was applied in heating the air.*

The furnace at the University Farm was not designed for the direct use of the gases of combustion, but in order to obtain a rough comparison of the relative efficiency of direct and indirect heating of the air, the furnace equipped with the air-blast burner was so arranged as to permit the gases of combustion to escape into the furnace room and to be drawn through the evaporator by a suction fan.

Tokay grapes were dried in 20 hours. The quality of the dried product was equal to that of the product dried by air heated in the usual way. A comparison of the temperatures attained, volume of air heated and fuel consumption in the two methods are shown in the following table.

TABLE 7.—EFFECT ON EFFICIENCY OF UTILIZATION OF FUEL OF HEATING AIR BY MIXING WITH GASES OF COMBUSTION

Observations	Radiated heat I	Direct use of gases of combustion II
1. Gallons of fuel per hour	8.8	6.7
2. Average temperature of outside air	69° F.	67° F.
3. Temperature of heated air	138.02° F.	145.2° F.
4. Rise in temperature	69° F.	88° F.
5. Volume of air per minute entering furnace room†	12,800	15,700
6. Relative efficiency of use of fuel, using volume of air heated, temperature rise and fuel consumption as basis for computation (test II taken as 100)	67.5%	100%

When the gases of combustion were used it was found possible to increase the temperature of the air entering the tunnel to 190° F. without difficulty. Temperatures of 165° F. to 175° F. were easily maintained.

* Calculation made by Mr. G. B. Ridley from calorific value of the fuel, and volume of air heated.

† Only two cars were in the tunnel during the test on use of gases of combustion. This gave less resistance to air than in first test and accounts for greater air flow and more rapid rate of drying.

The data given in the above table are the results of one test only; nevertheless, a much greater efficiency for the direct heating method is indicated. Further investigations will be made upon this point during the coming season.

Crude oil is a much cheaper fuel than stove distillate, but the gases of combustion from the former have not been used in drying because of the greater tendency for the formation of soot and smoke. Crude oil is, however, used very commonly in furnaces which heat the air by radiation. The question arises whether the greater efficiency of the use of the gases of combination from the burning of stove distillate will more than compensate for the greater cost of this fuel, as compared to the cost of crude oil which is used only in furnaces heating the air by radiation. We do not have sufficient data to answer this question; but it is a point which the builder of an evaporator must carefully consider.

(*k*) MOISTURE CONTENT OF EVAPORATED GRAPES

The yield of dried product varies in proportion to its moisture content; this fact makes it important for the operator to know the maximum percentage of water evaporated grapes may contain without becoming moldy or undergoing fermentation.

Sixty-one samples of dried grapes, including several varieties from the University Farm and from commercial evaporators, and eighteen samples dried in the laboratory were analyzed. The average moisture content of the University Farm and commercially dried samples was 13.83%; the minimum was 8.8%, and the maximum, 44.10%. This last sample had fermented and the very high moisture content indicated represents to a large extent loss from alcohol formed from the grape sugar. The average moisture content of the samples dried in the laboratory was 12.54%.

A commercial sample containing 30% moisture had undergone fermentation three months after the date of drying, although at one month the sample was free from any evidence of fermentation. Two samples from the University Farm containing 29.3% and 33.5% moisture, respectively, have not fermented or become moldy, but both lots had been heavily sulfured before drying, which probably accounts for their resistance to spoilage. Several lots which had not been sulfured and which contained 25% to 25.4% moisture have given no evidence of decomposition after four months' storage in sealed containers. A relatively larger number of samples containing between 20% and 25% moisture have kept perfectly. Therefore, it would appear to be safe to state that grapes dried to 24% or 25% moisture will not spoil and that 20% moisture content will certainly under Californian conditions not permit molding or fermentation.

The trade prefers dried grapes that have been stemmed and packed in fifty-pound boxes. Stemming can not be satisfactorily accomplished unless the grapes are reduced to approximately 10% moisture. This would necessitate a reduction in possible yield of 10% to 15% through the extra degree of drying necessary to permit stemming. However, in the commercial packing of Muscat raisins the moisture which is removed from the raisins in order to make stemming possible is returned by processing in hot water before the raisins are passed through the seeding machine; the final water content of the packed raisins being approximately 16% to 20%. Commercial practice has demonstrated that such fruit does not mold or ferment.

Therefore, it should be possible to return to the stemmed evaporated raisins enough water to give in the finished product that amount of moisture which causes the raisins to be of the most desirable texture; that is, about 20%.

As the dried grapes come from the evaporator they are not of a uniform moisture content; some bunches will be over-dry, others too wet. It is desirable to allow the dried product to stand in sweat boxes or bins for a number of days (probably at least two weeks) to permit equalization of moisture. This will be particularly necessary for stemmed dried grapes to which water has been added. Because of the small size of the individual berries, evaporated grapes equalize in water content more rapidly than do the larger dried fruits. It was observed that partially dried grapes from which juice could still be pressed easily gave up this excess moisture to the drier grapes in the sweat box before fermentation or molding could take place, provided the average moisture content of the whole lot was not too high.

The only method in common use which has proved accurate for estimating the moisture content of dried grapes consists in drying a weighed average sample of the finely ground raisins in a vacuum oven. A temperature of 90° C. (196° F.) may be used in this determination, provided the sample is not heated longer than necessary to remove all the water. Drying in an oven open to the air gave excessively high results at all temperatures used because of the loss in weight through oxidation of the fruit sugars. Preliminary experiments indicate that it is possible to estimate the moisture by a simple method based upon the distillation of the sample with a liquid immiscible with water. This method is sufficiently accurate to be very useful to operators of evaporators for controlling the moisture content of the dried product.

(*l*) THE DETERMINATION OF HUMIDITY

The efficiency of an evaporator depends largely upon the degree of saturation with moisture of the exhaust air. If the humidities of the hot air entering the drying tunnel and of the air leaving the tunnel are measured, the amount of moisture absorbed from the fruit may be easily calculated and the efficiency of the evaporator determined. Humidity may be determined by reading the temperature of wet and dry bulb thermometers placed at the desired points and by use of the following table. Explicit directions for use of thermometers and table are given in the discussion immediately following the table.

Two accurate Fahrenheit thermometers (of the variety known as "chemical thermometers") are the only instruments needed. Ordinary dairy thermometers reading to 180° F. or 225° F. may be used if chemical thermometers are not easily obtainable. Most drug stores carry thermometers of both types or can obtain them on short notice.

Special instruments may be used instead of the ordinary thermometers. One known as a "sling psychrometer" which consists of two thermometers mounted side by side on a narrow frame is very convenient and accurate. Another instrument is so constructed that humidity is read directly by means of a chart and pointer mounted upon the device itself. The Taylor Instrument Company's Hygrodeik is the most common form of this latter instrument. Its only fault is that it may be used only for temperatures up to 120° F.

Around the mercury bulb of one of the thermometers wrap a small piece of cheese cloth of five thicknesses and extending about one-half inch above the bulb. Be sure all of the bulb is covered with the cloth. Tie the cloth with thread or fasten with small rubber band.

Dip the thermometer with the cloth-covered bulb in water. Hang it beside the other plain thermometer at the point where the test is to be made. Watch the two thermometer columns closely. As soon as they remain at constant temperatures for about one minute read both carefully. It will usually require three to five minutes for the thermometers to come to constant temperature. Do not wait too long as the wet-bulb cloth will then dry out and the temperature will rise too high. *This point is important.* On the other hand, do not take this reading too soon as it will then be too low. A little experience will render readings fairly accurate. Now subtract the temperature of the wet bulb from that of the dry bulb. In the extreme left column of the table find the temperature nearest that of the dry bulb. In the

TABLE 8.—RELATION OF HUMIDITY TO DIFFERENCE IN TEMPERATURE OF WET AND DRY BULB THERMOMETERS

(After The Foxboro Company, Incorporated, Foxboro, Massachusetts, U. S. A., catalogue 101–1, page 9.)

Dry Bulb Deg. F.	Difference Between Readings of Wet and Dry Bulbs in Degrees Fahrenheit																																			Dry Bulb Deg. F.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60	65	70	
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	35	22	19	12	6	0	0													70
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	18	12	7	1	0												75
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	23	18	12	7	3	0											80
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38	35	32	27	22	17	13	8	4	0	0									85
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	31	26	22	17	13	9	5	1	0								90
95	96	93	89	85	82	79	75	72	69	66	63	60	57	54	52	49	46	43	42	38	34	30	25	21	17	13	9	6	2	0							95
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	37	33	28	24	21	17	13	10	7	4							100
105	97	93	90	87	83	80	77	74	72	69	66	63	60	58	55	53	50	48	46	44	40	36	32	28	23	20	16	13	11	8	0						105
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	42	38	34	30	26	23	20	17	14	11	4	0					110
115	97	94	91	88	85	82	79	76	74	71	68	66	63	61	58	57	54	52	50	48	43	40	36	32	28	26	22	20	16	14	7	2					115
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	45	41	38	34	31	28	25	22	19	17	10	5	0				120
125	97	94	91	88	85	83	80	78	75	73	70	68	66	63	61	59	57	54	52	50	47	43	40	36	33	30	27	24	22	19	13	7	2	0			125
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	48	45	41	38	35	32	29	26	24	21	15	10	6	1			130
135	97	94	92	89	86	84	81	79	76	74	72	69	67	65	63	61	59	57	55	53	50	46	43	40	36	34	30	28	26	23	18	12	8	3	0		135
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58	56	54	51	47	44	41	38	35	32	30	27	25	19	14	10	5	2		140
145	98	95	93	90	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	52	48	45	42	39	36	34	31	29	27	21	16	12	7	4	0	145
150	98	95	93	90	87	85	82	80	78	76	73	71	70	68	65	64	62	60	58	56	53	49	46	43	41	38	35	33	30	28	23	18	13	9	5	2	150
155	98	95	93	90	87	85	83	81	79	76	74	72	70	68	66	64	63	61	59	57	54	50	47	44	42	39	37	34	32	30	24	19	15	11	7	4	155
160	98	95	93	90	88	85	83	81	79	77	75	73	71	69	67	65	63	62	60	58	55	51	48	46	43	40	38	35	33	31	25	21	16	12	9	6	160
165	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	56	52	49	47	44	41	39	37	34	32	27	22	18	14	10	7	165
170	98	96	94	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63	62	60	57	53	50	48	45	42	40	38	35	33	28	23	19	15	12	9	170
175	98	96	94	91	89	86	84	82	81	79	76	74	73	71	69	67	66	64	62	61	58	54	51	49	46	43	41	39	36	34	29	25	20	17	13	10	175
180	98	96	94	92	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	58	55	52	50	47	44	42	40	37	35	30	26	21	18	14	12	180
185	98	96	94	92	89	87	85	83	81	80	77	76	74	72	70	69	67	65	64	62	59	56	53	50	48	45	43	41	38	36	31	27	22	19	16	13	185
190	98	96	94	92	90	87	85	83	82	80	78	76	74	73	71	69	68	66	64	63	60	57	54	51	49	46	44	42	39	37	32	28	24	20	17	14	190

topmost horizontal row of the table find the difference in temperature nearest that of *difference* in temperature between wet and dry-bulb thermometers. Follow down the vertical column directly beneath this difference in temperature until this vertical column cuts the horizontal row opposite the dry-bulb thermometer temperature. The figure at this point of intersection is the relative humidity. An example will make this explanation clearer:

Dry-bulb thermometer, 130° F.; wet-bulb thermometer, 103° F.; difference, 27° F.

Find in the row at head of table, 28° F. and follow down this column until the horizontal row to the right of 130° F. is met. At this point will be found 38, the per cent relative humidity.

To determine the increase in humidity of air passing through the evaporator determine the relative humidity of the hot air entering the evaporator and that of the exhaust air. Calculate both to the same temperature by use of the fact that each 27° F. drop in temperature doubles the relative humidity. The increase in humidity can then be calculated.

(*m*) MEASUREMENT OF AIR VELOCITY

The rate of air flow through the evaporator and especially over the trays determines the rate of drying. An instrument known as an anemometer, which consists of a small disc fan made up of small vanes attached to a pinion connected to several dials, is used to measure the velocity of air currents. It is placed with the revolving vanes facing the air current. The "hundreds" dial is read. The clutch is released and the instrument allowed to run for exactly one minute and the dials read again. The difference between first and second reading of "hundreds" dial gives the velocity of the air in hundreds of feet per minute. The velocity should be in a horizontal blast evaporator at least 300 feet per minute over the trays at the exhaust end of the tunnel. It should be possible to reach 500 feet per minute at this point if the evaporator has been properly designed and built.

Anemometers may be had from chemical supply houses or from dealers in heating and ventilating equipment. The one used by the University cost twenty-five dollars. The Pitot tube is an instrument used to measure static pressure in the drying tunnel and is a useful check for the anemometer.

(*n*) EXPERIMENTS ON STEMMING, SEEDING AND PACKING

In order that evaporated grapes may be stemmed successfully they must be dried to a moisture content of about 10 per cent or less and must be transferred to the stemming machine within a short time (a few hours) after the grapes emerge from the evaporator. They are at this time very dry on the surface and for a short distance into the flesh, a condition which gives sufficient rigidity to the berries to permit stemming. After standing over night the moisture near the center of the raisins diffuses toward the surface and moisture is absorbed from the air, causing them to become so soft and pliable that stemming is difficult. The stems of freshly dried grapes are dry and brittle but after a few hours' standing become wiry and difficult to remove in the stemmer.

A test was made at a commercial evaporator to determine the loss in weight during stemming. Two hundred and eighty pounds of over-dried Alicante Bouschet grapes were passed through a cleaned stemming machine. Stemming was very satisfactory, but few grapes being lost with the stems. The weight of the stems removed was 5.7 per cent. The raisins were not passed through a cap stemmer although many of the cap stems were removed. These grapes had been gathered in such a manner that pieces of cane four to six inches long were left on many of the bunches. This would probably cause the loss in weight during stemming to be higher than the average for grapes picked in the usual manner and this figure should therefore be a conservative one for the calculation of loss due to stemming dried wine grapes under average conditions.

Through the coöperation of L. R. Payne of the California Associated Raisin Company of Fresno stemming and seeding tests were made at the Fresno plant of the above company upon small lots of dried Petite Sirah, Semillon, and Muscat grapes. The following table contains the results of Mr. Payne's tests. Because the lots were so small the results on losses during stemming and seeding are excessively high, but are still of value for comparison with losses in stemming and seeding Muscat raisins under the same conditions. The results given below do not take into account the water returned to the fruit before seeding.

TABLE 9.—LOSSES DURING STEMMING AND SEEDING EVAPORATED GRAPES.

Observations	Muscat, per cent	Semillon (white wine grapes), per cent	Petite Sirah (red wine grapes), per cent	Sultanina (Thompson seedless), per cent
1. Stemmer loss	13.69	7.81	13.39	10.20
2. Drier loss	2.4	7.4	10	10.5
3. Loss in seeding	10.46	16	31.11	....
4. Total loss in stemming and seeding	24.05	23.81	44.50	10.20 (seedless)

The results indicate that the loss in seeding of dried wine grapes whose berries are above the average in size is not much greater than that of Muscat raisins, while the loss in seeding dried wine grapes with small berries (Petite Sirah) is about three times that of Muscat raisins. The tests at least indicated that it is possible to remove the seeds from such dried grapes, although it is doubtful whether such a product could be produced as economically as seeded Muscat raisins.

The seeded Petite Sirah raisins were of excellent flavor and practically free from pieces of broken seeds. Tests were made of their suitability for culinary use. Pies made from them resembled blackberry pies in flavor, color and general appearance. A slightly astringent flavor was noticeable if the dried grapes alone were used but this defect was overcome when the raisins were mixed with an equal quantity of chopped apples. These raisins will give excellent results in various puddings, cookies, cakes, and candy in which they may be used to replace Muscat raisins in the usual recipes.

If seeded dried red wine grapes can be produced and sold for a price not greatly in excess of that received for Muscat or seedless raisins it should be possible to develop an extensive market for them.

During the past season the dried grapes were sold in the unstemmed condition in sacks and boxes by some producers; others packed the stemmed unseeded product in fifty-pound boxes. These latter brought the best prices and it is probable that this method of packing will be adopted generally in the future.

The machines used for stemming muscat raisins have proved satisfactory for dried wine grapes, although as previously stated the raisins must be thoroughly dry if satisfactory results are to be obtained.

VII. SUMMARY

1. An evaporator of the horizontal tunnel air-blast type and of six tons of fresh fruit capacity per charge was constructed on the University Farm at Davis during 1919 by funds furnished by the State Board of Viticultural Commissioners and the University. This evaporator was used successfully in the drying of grapes and prunes. Plans, cost, and general specifications of this evaporator are to be found in the text of this publication. Sketches indicating revised evaporator plans recommended to growers have been given. The recommended evaporator is of the same capacity and general appearance as the University Farm evaporator but embodies the improvements which we have found desirable to increase the efficiency of the plant. The evaporator can be constructed for about $3,500. We

believe the recommended evaporator to be equal in efficiency to any evaporator of similar capacity now in use and superior to many. It is not expensive to construct and can be erected by local artisans.

Most of the suggested improvements are now being made in our plant. Therefore, growers who contemplate the erection of evaporators are urged to visit the University Farm.

2. Dipping of grapes in a dilute boiling lye solution approximately doubled the rate of drying. Most wine-grape varieties and Muscat grapes require a lye solution of 2% to 3% for effective results. Tokays and Thompson Seedless require only a ½% solution.

3. Grapes dried in the evaporator were improved by a short period of sulfuring before drying. Much less sulfuring was required for grapes dried in the evaporator than for those dried in the sun.

4. No definite constant difference in yield could be found in sun-drying and evaporation. The color and flavor of the juice obtained by soaking sun-dried grapes in water was much inferior to juice obtained from evaporated grapes.

5. The rate of drying is greatly increased by increase in temperature of the air used in drying. Temperatures up to 190° F. were used successfully on red-wine grapes, although it was found necessary to remove the grapes from the evaporator as soon as dry, to avoid injury to color and flavor. A temperature of 165° F. may be used in regular practice.

6. Recirculation of a large proportion of the exhaust air from the evaporator greatly reduces fuel consumption without reduction of the rate of drying. Recirculation prevents overdrying of the fruit and permits regulation of moisture content of the dried product. It is believed that higher temperatures of drying may be employed where the humidity of the air used in drying is increased by recirculation.

7. The suction type of fan proved more satisfactory than the blast type. The multivane fan was found to be much more efficient than the disc type.

8. The air-blast distillate burner was more satisfactory than the gravity burner, although both were used successfully.

9. Dried grapes of 25% or less moisture have kept perfectly; those of 30% or over have spoiled unless heavily sulfured. The dried product equalized rapidly in moisture content in sweat boxes.

10. Dried grapes stemmed satisfactorily when dried to about 10% moisture and stemmed within a few hours after drying.

11. The dried grapes adhered with great tenacity to screen trays but were easily removed from slat-bottom trays. Grapes dried as rapidly on the latter as on the former. The slat-bottom trays are of greater durability and lower cost than screen trays.

12. Dried wine grapes were seeded successfully but the loss during this process was excessively large. The seeded product gave excellent results when used for pies, puddings and other dishes. Dried white wine grapes gave fair results on seeding but the finished product was inferior to Muscat raisins. Seeded dried wine grapes appear to have possibilities for culinary use.

13. *Evaporator manufacturers.* A list of manufacturers of evaporators and dealers in evaporator equipment will be sent on request made to the Division of Viticulture and Fruit Products.

14. *Nomenclature.* At the present time various terms are applied more or less indiscriminately to fruits and vegetables from which most of the water has been removed in order to preserve the product. At a convention held in San Jose on evaporation a committee consisting of A. W. Christie, Paul F. Nicholls, E. M. Sheehan, H. C. Rowley, and S. C. Simons was appointed to consider this question. The committee's report, which has been approved by the College of Agriculture through a committee consisting of J. C. Whitten, M. E. Jaffa, W. V. Cruess, E. L. Overholser, and J. P. Bennet is as follows:

a. The same nomenclature shall be applied to fruits and vegetables.

b. The term "dried" is applied to all fruits and vegetables preserved by the removal of moisture, irrespective of the method of removal.

c. There are but two classes of dried fruits and vegetables, namely, those dried principally by solar heat and those dried principally by artificial heat.

d. The class dried principally by solar heat shall be designated "sun-dried," by which is meant the removal of moisture by solar heat without control of temperature, humidity, or air flow.

e. The class dried principally by artificial heat shall be designated either "evaporated" or "dehydrated." The committee finds at this time no sufficient reasons for distinguishing between "evaporated" and "dehydrated."

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